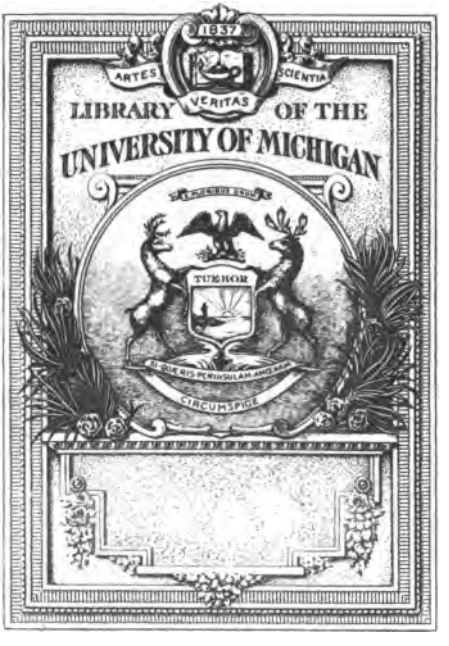

PERMANENT FORTIFICATION

PREPARED FOR THE USE OF THE CADETS OF THE
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BY

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CHAPTER I.

LAND DEFENSES AND THEIR DEVELOPMENT.

Permanent land defenses are the fortifications which are constructed on the land frontiers, or in the interior of a country, during time of peace, in anticipation of invasion at some future time by a hostile army. Their object is to assist the land forces of a nation to defend it against such invasion, by rendering selected strategical points secure against the operations of the hostile army.

Land defenses therefore bear the same relation to strategy as hasty intrenchments do to battle field tactics; the object of each is to increase the resisting power of a body of troops detailed to hold a point which is important both to the defense and to the attack.

Classes of Land Defenses.—The permanent land defenses which are being constructed, or are of military value to-day, may be divided into *barrier forts* and *intrenched camps.*

Barrier Forts.—A barrier fort, or *fort d'arrêt*, is any fortification which is intended to arrest the advance of a hostile army at some point on a natural line of operations. They are usually constructed in a mountainous country, where railways and highways are widely separated and are confined to narrow valleys or cañons, which render it impossible to construct branch lines around the forts. The following historical examples explain the functions of these fortifications:

In the spring of 1800, while one part of the Austrian army in Italy was besieging General Massena in Genoa, and another was pursuing General Suchet through Nice, Napoleon was secretly organizing in Switzerland the Army

of the Reserve of 40,000 men with which he proposed to relieve both his generals. His plan was to cross the Alps at the Great St. Bernard pass, move rapidly down the valley of Aosta, and place himself along the Ticino between the Austrian army and its base, thus compelling the latter to retreat and to fight for its communications. On the 15th of May, his army began to cross the mountains, and four days later the advance guard was stopped by Fort Bard on the Doria river, which prevented the passage of its artillery and wagons. This fort consisted of a citadel on a high, isolated rock close to the river, and only one hundred and twenty-five yards from the highway through the valley. The citadel was surrounded by two exterior walls, had a garrison of 400 men, and an armament of 18 guns. For a time it seemed as though this little fort would defeat the plans of Napoleon and render useless the passage of the Alps. Six days were spent in constructing trails over the mountains for the passage of the cavalry and infantry, during which time every available effort was made to compel the small garrison to surrender. As these efforts were fruitless, and as the other arms needed the support of artillery, it became necessary to force the passage. The guns were therefore moved by at night, precautions being taken to reduce the noise by wrapping the wheels with straw, and to conceal the movement by making a cloud of smoke. In spite of these precautions many of the pieces were dismounted by the fire of the fort. Even when the army had passed, the fort was still a dangerous obstacle on the line of retreat in case of defeat, therefore Napoleon was compelled to detach a division to take it by regular siege.

Had Fort Bard not stopped the advance of the army, it is probable that Genoa never would have fallen, as the Austrian army besieging that place received orders to raise the siege and join the main body on the very day, June 2nd, that Massena had exhausted his supplies and was compelled to surrender.

In the Franco-German war the fortress of Toul, [Pl. XV] controlled the Paris-Strasburg railway. It was an old work with a weak garrison, a defective armament, and was commanded on all sides by heights only a mile away. The Third German army appeared before it on the 14th of August and after a futile bombardment left an investing force and marched on.

"Although the fortress placed no important obstacle in the way of the advance of the Third army, still the transport of supplies and stores of every description was much delayed, in spite of the use of numerous by-roads, and ran some risk from the attacks of marauding gardes-mobiles and franc-tireurs. The conveyance of sick and wounded to the rear became continually more difficult as the army advanced, and the time was indefinitely post-poned when it would be possible for the transport depart-ment to bring to the front, as rapidly as was desired, the artillery stores of all descriptions required for the contem-plated siege of Paris. Our complete and excellent railway organization became paralyzed at Toul, so that even at this time the advisability of constructing a line branching off from Frouard was being considered. Thus from the undeniable present strategical importance of the fortress, the occupation of Toul had become for us a necessity." Tiedemann—"Siege Operations in the Campaign against France."

Toul fell on the 23rd of September, about one week after the complete investment of Paris. Had it been a first-class barrier fort, well supplied with provisions and ammunition, the Germans would have been obliged to con-struct the branch line mentioned, notwithstanding the un-favorable topographical features of the country.

A simple barrier fort is usually planned for passive defense only, the garrison, armament, and supplies are thoroughly protected from bombardment and advantage is taken of the topographical features of the site to render an assault impracticable, and a siege very difficult.

Intrenched Camps.—An intrenched camp as its name

implies is a fortress of very great magnitude which may become the refuge of a defeated and demoralized army. It can only be invested by a large force, and is defended by active as well as by passive measures. In one sense it is a battle field organized for defense by occupying the supporting points with permanent fortifications. The line of defense forms the perimeter of a polygon, and incloses either a military nucleus consisting of arsenals, depots of supply, etc., or a civil nucleus consisting of some important political or commercial centre. If no civil centre is inclosed, the camp is called a military camp. The theoretical distance of the line of defence from the nucleus is usually about four and one-half miles, which is based upon the extreme bombarding range of heavy siege artillery, and the distance at which these batteries can be established in front of the line of defense without first capturing that line. The extreme bombarding range is about six miles, and the least distance of the bombarding batteries from the line of defense is assumed to be one and one-half miles. In actually locating the line of defense upon the ground, this theoretical distance is varied to conform to the topographical features of the site, and the strategical or tactical functions which it must fulfil. In the defenses of Strasburg, for topographical reasons, the line of defense constructed between 1870 and 1880 is from 2.5 to 5 miles from the nucleus, and in the defenses of Paris, constructed about the same time, for military and political reasons, the line of defense is 7.5 miles from the nucleus. The line of defense is a *line with intervals;* that is, it consists either of single redouts or forts, or groups of works, upon the supporting points, separated by intervals, which vary from one to three miles. The interval between the individual works, or groups of works, is dependent upon their separate strength; because the weaker the work, the more necessary will be the support of the adjacent ones. The theoretical intervals are greatly modified by the topography of the site and by the military functions of each work or group. In the defenses of Strasburg, for topographical

reasons, the intervals on the west bank vary from 0.9 of a mile to 2.7 miles. In the defenses of Paris, for topographical and financial reasons, there are two undefended intervals of 9.3 miles between adjacent groups of works in the exterior line.

Inner Line of Defense.—If a line with intervals were the only barrier guarding a large city, and the garrison were comparatively weak, it would be possible for an energetic assailant to penetrate the intervals with a raiding party under cover of darkness or fog, and capture or destroy the city without attacking the forts. To defeat such a movement it is customary to surround the city with an *enceinte* or *continuous line* of fortifications; that is, a line without a break in the continuity of rampart, parapet and ditch. A fortification which will defeat the efforts of a raiding party with field-guns is considered sufficiently strong for the inner line.

Barrier forts and intrenched camps are employed either singly, or in combination, to form bridge-heads, pivots of maneuvre, fortified curtains, and fortified regions. *Bridge-heads* are constructed around the bridges over wide deep rivers in such a manner as to secure the bridges from attack, and to allow the defending armies to operate with safety on either bank. *Pivots of maneuvre* are large fortifications which serve as pivoting points for the operations of an army in the field. *Fortified curtains* are lines of fortification, constructed near an open frontier to bar the advance of an invader; they usually consist of intrenched camps connected by a line of barrier forts. *Fortified regions* are tracts of country surrounded by a number of intrenched camps; the camps are distant two or three days' march from one another. The region serves as a refuge to a large army in retreat, in which it cannot be invested.

The great fortresses of the Rhine, Cologne, Mayence, and Strasburg [Pl. XV] are bridge-heads, which will cover the advance and retreat of the German armies across that river. Metz [Pl. XV] is a pivot of maneuvre which will support one flank of a German army operating in the

province of Lorraine. The eastern frontier of France (Pl. XV) has two defensive curtains Verdun to Toul and Epinal to Belfort, which will be described hereafter. The celebrated quadrilateral of Italy comprising the fortresses of Verona, Legnano, Peschiera, and Mantua is an intrenched region; intrenched regions also form part of the new defenses of France and Russia.

Effect of Means of Attack.—The art of permanent fortification is dependent upon the weapons and machines especially designed for the attack and defense of permanently fortified positions. Before the invention of gunpowder, a high inclosure wall with a pathway or boulevard on top, protected by a crenelated parapet wall, and also provided with a machicoulis gallery or flanking towers, was sufficient to ward off an attack by an enemy, whose weapons were spears, bows, and slings, and whose machines were scaling ladders. When the besieger invented the battering ram, the defender strengthened his wall by constructing counterforts and backing his wall by a heavy mound of earth. Attack by mining was met by the construction of a wide, deep ditch in front of the wall. The invention of gunpowder led the besieger to replace the battering ram by guns which could destroy the walls across the ditch. The defender met this attack by masking his wall by a glacis, and by constructing additional works beyond the ditch, which prevented the besieger from establishing his batteries upon the glacis until he had captured these advanced works. The wall was still considered the main line of defense, and to prevent the enemy reaching it, the ditch was thoroughly swept by fire of artillery and small arms. As the besieger improved his artillery, the defender was obliged to move his advanced works still further to the front. In some fortifications these works were built in front of the glacis, but in close range of it, and in others they were practically detached from the main line of defense, and beyond supporting distance from it. When rifled artillery was introduced about the middle of this century, the general character of the permanent land fortifications

in existence was as described above [Pl. II]. A continuous wall, 30 to 36 feet high, with a continuous parapet for the artillery and infantry in its rear, extended around the city. In advance of this wall was a dry or wet ditch, 60 or more yards wide, and beyond the ditch were a number of additional works also surrounded by ditches, which could be swept by the close fire of the works in rear, or from the main work. Surrounding all the works was a glacis which masked all walls from the fire of the enemy. A few fortifications had works beyond the glacis. The defenses were as a rule open defenses with few bomb-proofs, and were especially designed to protect the defenders against ricochet fire, the most dangerous fire which could be brought against them.

The Franco-German war was the first in which rifled siege artillery was used against the permanent works. In 1864 the Prussians introduced into their armament the 15 c. m. (5.9 inch) rifled siege-gun, and in 1870 the 15 c. m. siege howitzer, and the 21 c. m. (8.3 inch) rifled siege mortar. With this artillery the Germans were able to destroy existing bomb-proofs, breach scarp walls masked by a glacis as then constructed, render open shelters untenable, and bombard cities at a range of about five miles. Out of twenty-five castles and fortified cities taken by the Germans, four made no defense whatever, and sixteen yielded after one or more bombardments; many of them being bombarded by rifled field-guns only. Modern fortification may then be said to date from this war, since which time several million dollars have been spent by each of these two countries alone, in modifying the permanent fortifications on their common frontier.

Modern Artillery.—While few pieces of greater calibre than those used by the Germans in this war have since been introduced into the heavy siege or fortress artillery of any country, many changes have been made to render the pieces more effective. By the use of better steel, longer guns, and smokeless powders, the range and accuracy of the siege-gun, howitzer, and mortar have been greatly in-

creased; and by the use of shrapnel and torpedo shells in curved and vertical fire, the howitzer and mortar have almost supplanted the gun in attack and defense. The introduction of machine and rapid fire guns has greatly aided the defense in reducing the size of the garrisons for passive defense, and the extent of shelter required for the same amount of fire delivered. The latest types of heavy siege and fortress artillery have all been introduced since 1880. The standard calibres are the 15 c. m. and 12 c. m. guns, and the 21 c. m. and 15 c. m. howitzers and mortars. The extreme ranges, of the guns are from 8,000 to 11,000 yards, of the howitzers 5,500 to 8,000 yards, of the mortars 5,000 to 7,000.

The guns are employed with shrapnel against live targets at all ranges and against captive balloons; with torpedo shells, against live targets, to breach masonry, to destroy villages, camps, and parks, and to destroy guns which project from armored turrets and shields. The howitzers and mortars are employed with shrapnel and torpedo shells to reach live targets protected by open or covered shelters, and with torpedo shells to destroy earthworks and all varieties of bomb-proofs and magazines.

CHAPTER II.

PROFILE AND TRACE.

Nomenclature of the Profile.—Pl. I, Fig. I, is the profile of a permanent fortification in which

AB is the plane of site.

TU, the surface of the ground in the interior of the work, is the *parade.* The mound of earth which is constructed on the plane of site and which is limited by the planes OP and AB, is the *rampart.*

RS, the wall which terminates the rampart in rear, is the *parade wall.*

OP and QR, the horizontal surfaces of the rampart are the *terre-pleins;* OP the *upper*, and QR the *lower.*

PQ is the *rampart slope.* A similar slope connects the lower terre-plein and the parade in some works.

MNO is the *parapet*, the planes and lines of which have the same designations as in field fortification.

L is the *berm.*

FGHIKL is the *ditch.*

LK is the *earthen scarp.*

K is the *exterior corridor.*

IJ is the *detached scarp wall.*

H is the *cunette.*

FG is the *counterscarp wall.*

FE is the *covered way.*

CDE is the *glacis.*

The thickness, height, command, and relief of the parapet are measured as in field fortification. The principal line of works with masonry scarp walls, is the *magistral*, or line of intersection of the face and top of the scarp wall. It is the line from which all measurements

are made in the trace, and the first line marked upon the ground in laying out the work.

Parade.—In large works the parade coincides with the site upon which the fortification is built; in small ones it may be above or below the site.

Rampart.—In early fortifications the rampart was made high enough to give the interior crest of the parapet a command of from 20 to 30 feet over the plane of site and this height is retained in some modern works. On account of the extreme accuracy of modern artillery, the very recent works have little command over the ground in their immediate vicinity, so that they may be better concealed from the assailant's batteries. Underneath the rampart are the bomb-proofs for magazines, quarters, etc.

Parapet.—To resist the continued fire of heavy siege-guns, the parapet is made from 23 to 26 feet thick, the angles in the profile are rounded, and the exterior slope is given as little inclination as practicable. In the most recent works the triangular profile is employed as it is less easily destroyed by torpedo shells of howitzers and mortars; the parapet is made about 40 feet thick.

Terre-Plein.—In early fortifications there was but a single terre-plein, from 14 to 16 yards wide, which served as a barbette for artillery, and formed a wide roadway around the work in rear of the guns. As curved fire became more accurate, the roadway was made at a lower level and formed a second terre-plein. In the most recent works, the artillery is either protected by armor, or is placed in separate batteries, and the communications are protected by overhead cover; the terre-plein has therefore ceased to be of any special value and is simply a limiting surface of the rampart.

Ditch.—A ditch 30 to 60 yards wide and 18 to 20 feet deep, with masonry scarp and counterscarp, was one of the principal features of all permanent fortifications until 1886; since that time there has been a tendency to adopt the triangular profile with a shallow ditch, and rely more upon

the fire from the parapet and obstacles in the ditch, to protect against open assault.

Cunette.—The cunette is an open drain constructed in the bottom of the ditch. In wet ditches, the increased depth renders the ditch a more formidable obstacle.

Scarp.—When artillery was not very powerful, the rampart was supported by a masonry retaining wall 30 to 36 feet high, strengthened by counterforts or relieving arches. This was call a *full scarp*. In the re-entrants, the relieving arches were often converted into galleries for the defense of the ditch. As artillery became more powerful, the upper part of a full scarp was easily destroyed by its fire, and the debris falling into the ditch formed a practicable breach. To remedy this defect and still retain the full height as an obstacle, the scarp was made a retaining wall only to a height of about 20 feet; above this was a loop-holed wall for infantry with a corridor in rear for communication. In this form it was called a *semi-detached scarp*. With the introduction of rifled artillery, curved fire became more accurate, and it became necessary to mask all masonry from projectiles grazing the crest of the glacis with a fall of $\frac{1}{10}$, then $\frac{1}{6}$, and finally $\frac{1}{4}$. To meet this requirement the height of the scarp was decreased to 18 feet, and it ceased to be employed as a retaining wall for the rampart. In this form it became a *detached scarp* as shown in the profile. On account of the shattering effect of torpedo shells, detached scarps are in recent works, replaced with wrought iron fences or barriers which are less easily destroyed.

Counterscarp.—A high masonry counterscarp has usually been one of the obstacles to impede the assailant in an open assault. As this wall cannot be reached by direct or curved fire, it is still frequently retained in modern constructions. A gallery is constructed behind the counterscarp which serves to flank the ditches, and as a base for countermining operations. Where the ditch is wide and has a depth of water of at least six feet, masonry scarps and counterscarps may be omitted.

Covered Way.—In early works, a covered way ten or more yards wide, was a very important feature of a fortification, as it was the base from which all sorties were made against the assailant. At the present time sorties are not made from the work itself, and as a wide covered way exposes the scarp slope and barrier to curved fire which grazes the crest of the glacis, it is wholly omitted or its width is decreased to one yard and serves as an outpost line for sentries.

Glacis.—The glacis is constructed to remove all dead angles in front of, and near, the fortification. With low commands the glacis almost disappears.

Trace.—The trace of a fortification is usually designed by laying out on the plane of site, a broken line, separating the positions or objects which are to be held, from the positions which may be occupied by an assailant. Each part of the broken line is called an *exterior side;* and all the works constructed along any exterior side constitute a *front* or *front of fortification.* In the construction of fortifications since the use of gunpowder, two distinct designs of fronts have been employed: the bastion and the polygonal.

Bastion Trace.—The bastion front [Pl. I, Fig. 5] is sometimes called the French front from its general use in that country, although it originated in Italy in the 16th century. It is based upon the flanking of the ditch from the parapet of the main work in its rear. The trace is constructed by bisecting the *exterior side*, AF, by a perpendicular GH, and making GH equal to $\frac{1}{8}$ to $\frac{1}{6}$ of AF; the two lines AH and FH prolonged are united by a line CD parallel and equal to about $\frac{1}{3}$ AF. The lines BC and DE are drawn so as to make an angle of 100° with CD. The resulting broken line ABCDEF is the magistral of the bastion front, of which AB and EF are the *faces*, BC and DE the *flanks*, and CD the *curtain.* The angles at A and F are the *salient angles*, those at B and E the *shoulder angles*, and those at C and D are the *curtain angles.* The part of the work limited by the lines CBABC is called a

bastion. The two lines of the counterscarp IJ and JL are drawn from the shoulder angles to the points I and L which are fixed by the desired width of ditch. The interior crest of the parapet MNOPQR is approximately parallel to the magistral. From the construction it is evident that if the flanks of the interior crest NO and PQ have the proper relief, fire delivered from them parallel to the superior slope may reach the bottom of the ditch along the line GH, and conversely, if the relief be fixed, the length of the curtains may be modified to secure the same result. Then if the lines AD and CF, the *lines of defense*, do not exceed the close range of the flanking weapons, the ditch may be thoroughly swept from the flanks of the parapet. In the bastion front as usually constructed, the exterior side was 360 yards. As counterscarp galleries and armored caponiers can be protected more easily from the projectiles of the besieger's artillery than the open parapets or scarp galleries of the flanks, the bastion front is no longer employed on the exposed fronts of permanent works.

Polygonal Trace.—The polygonal front [Pl. I, Fig. 2] is also called the German front from its general application in that country although properly it had its origin in France in the beginning of the 18th century. It is based on the flanking of the ditches from caponiers constructed in them. The magistral usually coincides with the exterior side AB; the caponier is constructed at its middle point; the counterscarp is parallel to AB, except in front of the caponier where it is broken so as to separate the caponier from the covered way; and the interior crest of the parapet is also parallel to the magistral. The total length of the front is usually from 1000 to 1200 yards and may be twice the close range of the weapons used in flanking the ditch. The front may be modified as shown in Pl. I, Figs. 3 and 4, by breaking the front into two faces, and placing the caponiers either at the salient or at the re-entrant angles. In small works the ditches may be flanked equally well from the counterscarp galleries. Other advantages of the polygonal over the bastion front are the greater volume of

front fire, the smaller development of parapet, and the easier protection of the parapet from enfilade fire.

Outworks.—The outworks of any front are the separate defensive works which are constructed between the scarp of the main work and the crest of the glacis. They are utilized to increase the distance between the fortification and the investing lines of the besieger, to form a base for sorties, to bring the foreground under cross fires which enfilade the besieger's trenches, to conceal the outlets of the main work, to mask all scarp walls, and to compel the besieger to fight for every inch of ground up to the scarp of the main work. On account of the great range and accuracy of modern fire-arms, many of the outworks have lost their value, and are no longer constructed.

Pl. II is a trace of an early work designed in accordance with the principles of the bastion system. The outworks are A, the *tenaille* which masks the scarp wall of the curtain and flanks; B, the *counter-guard*, a face cover which masks the scarp wall of the bastion; C, the *ravelin* or *demi-lune*, which crosses its fires with the bastion face and also covers the outlets of the main work; D, the *ravelin* or *demi-lune redout*, which is in the keep or citadel of the demi-lune; E, the *tenaillon*, a face cover which masks the scarp of the demi-lune; F, the *covered way* of which G is the *salient place of arms*, and H, the *re-entrant place of arms* for assembling sortie parties to attack the works of the besieger.

Advanced Works.—Advanced works are constructed beyond the crest of the glacis, but within close range, so that the outworks may assist in their defense. In Plate II, the advanced works are *redans*, *lunettes*, and I, a *hornwork*. A *crown-work* is an advanced work similar to a hornwork, in which two bastion fronts replace the one of the hornwork.

Interior Works.—Interior works are additional defensive works constructed behind the parapet of the main work. In Pl. II, K, is a *cavalier*, or high mound of earth constructed in a bastion to give a plunging fire on the foreground.

Pl. III is the trace of a portion of one of the principal fronts of the *enceinte*, or *interior line* of the defenses of Antwerp, Belgium, constructed between 1860 and 1864. It is designed in accordance with the principles of the polygonal system, the exterior side being about 1100 yards long. The outworks are A, the *covered way*, B, the *ravelin* with a *reverse battery* at C and a *low battery* at D to sweep the ravelin ditch, E, the *counter-guard* or *face-cover* which masks the masonry walls of the head of the caponier, F, the *caponier*, whose casemated batteries sweep the main ditch of the front, G, the *cavalier* which gives a plunging fire on the foreground, and H, the *defensible barracks* which is the keep of the front and is surrounded on the interior by a palisade. In designating the different parts of the front the terms face, flank, and curtain are used as in the bastion front; thus IJ is the *face*, LM and MN the *first and second flanks*, and NO the *curtain*. The parapet along JK is called an *orillon* and serves to mask the flanks. On account of the low site, the fronts of Antwerp are protected by wet ditches without masonry scarps.

CHAPTER III.

LAND DEFENSES AS CONSTRUCTED BETWEEN 1870 AND 1880.

The remarkable results effected by the artillery in the Franco-German war, led to a reorganization of the land defenses of many of the European states. It was evident to the military authorities that all the principal fortifications of a country must be intrenched camps, and that a line of detached forts must hereafter be the principal line of defense. The first step was, therefore, the development of a type of detached fort which would meet the requirements of the new rifled artillery.

The conditions which the new works were to satisfy were, a heavy armament of guns well protected by traverses from enfilade fire; ample bomb-proof quarters and communications for the garrison, and magazines for supplies during time of siege; security against capture by open assault; protection of all masonry from projectiles having an angle of fall of ¼.

Type of Works.—Pl. IV, represents the trace, and Pl. I, Fig. 1 is the profile of a fort developed by the Germans just after the Franco-German war, and employed in the defenses of Strasburg, Cologne, Metz, etc. This type with slight modifications has also been employed in France, Italy, and Austria.

Trace.—The work is a lunette of which the faces are each 160 yards, and the flanks, each 125 yards, measured along the magistral. The salient angle is 150° to reduce as much as possible the sector without fire, and to protect the faces from enfilade fire; the shoulders are each 120°, to remove as much as possible the sector without fire and permit each flank to sweep the interval between

the forts, and the approaches to the adjacent forts. The gorge has a bastion front with a curtain of 60 yards and faces of 155 yards each. These dimensions give a work which admits of a maximum artillery armament of twenty-six heavy and six light guns; nine of the former are on each face and four are on each flank, well protected by traverses. The garrison is about five hundred men. The command of the work is 28 feet, which makes it conspicuous, but gives it a wide field of view and fire. Ample quarters for the men are placed along the gorge, and magazines for ammunition, supplies, etc., under the rampart of the faces, flanks, and the great central traverse. Covered communications connect all parts of the work. The traverses instead of being made solid are hollow, and are bomb-proof shelters for men, light guns, and ammunition. The fort is protected against capture by open assault by a wire entanglement on, or in front of, the glacis, by a detached scarp 18 feet high along the faces and flanks, by a full scarp about the same height along the gorge, and by a masonry counterscarp 20 feet high extending entirely around the work. The ditch is swept by eight or ten rapid fire or machine guns, placed in a caponier at the salient angle, in two half caponiers at the shoulder angles, and in scarp galleries in the flanks of the gorge. A bomb-proof guard-house is constructed in the ditch at the middle of the gorge. Galleries for countermining operations extend from the counterscarp galleries at the salient and shoulder angles. The armament of the work comprises 15 c. m. and 12 c. m. guns along the faces for use against the lines of investment and any visible works of the besieger; siege howitzers along the flanks for sweeping the intervals and approaches of the adjacent works; field and rapid fire guns which are kept in bomb-proofs and in the course of the siege are moved upon the rampart for the near defense of the work; and field or siege mortars to bring a vertical fire on the besieger's trenches.

In France, the results of the siege of Paris led to the abandonment of the bastion trace which had been the basis

of its system for several centuries, and the adoption of the polygonal to all the new works. Recognizing the difficulty of defending the parapet both by infantry and artillery, the French engineers attempted to separate the infantry and artillery in the defense. They accordingly adopted two types of works similar in outline to the German work but of greater depth. Each had a large central traverse parallel to the front which formed a cavalier and also a parados for the gorge. In one type this cavalier was reserved for the artillery, and the infantry was assigned to the low parapet which encircled the work. This had the advantage of securing a good command for the artillery, but had the disadvantage of rendering the guns conspicuous and thus increasing the chances of their being dismounted. This type was also employed in Austria and Russia. In the other type the low parapet of the faces was assigned to the artillery and the cavalier to the infantry. The position of the artillery was thus concealed from the assailant but it had the disadvantage of rendering dangerous, percussion projectiles which struck the parados during the artillery duel which precedes an attack. In both types the casemated quarters were under the cavalier. Eventually both types were abandoned for one similar to the German fort consisting of a single parapet.

Interior Line.—The German engineers were not ready to abandon the inner line, and in their new works they either retained the old lines or constructed new ones. All new lines were usually continuous lines of polygonal fronts, like the front of Antwerp, but without its elaborate outworks. These were limited to the caponier which was thoroughly protected from distant fire, even by armor if necessary, and a ravelin in front of the gateways. The counterscarp was revetted to a height of twenty feet, but there was no scarp revetment of any kind. In the French works, the old lines of works were left but no new ones were constructed.

Example.—Strasburg may be taken as an example of an intrenched camp constructed between 1870 and 1880.

Strasburg (Pl. V) is on the left bank of the Rhine river, nearly two miles from the principal branch of the stream, and a short distance up-stream from its junction with the Ill, which passes through the city. It is situated on level ground which is almost marshy in places. The numerous branches of the Rhine which surround wooded islands of considerable size, increase the defensive value of the river as an obstacle. On the left bank, the nearest heights are the foot hills of the Vosges mountains. The most noticeable feature in the landscape surrounding the city is the Hausberg ridge occupied by forts IV, V, VI; it rises to a height of about 168 feet. Beyond towards the west, the ground rises gradually, but in gentle slopes and all ridges are lower than the one just mentioned. On the right bank of the Rhine the ground is even more marshy than on the left. For a distance of four to four and a half miles, it is cut up by numerous creeks which empty directly into the Rhine, or into a tributary of the Rhine, which joins it at a short distance north of the village of Kehl.

Strasburg owes its military importance to the fact that it covers one of the principal railway bridges across the Rhine. From it radiate the railways and great highways of the Rhine valley.

Detached Forts.—The forts of Strasburg are fourteen in number, and are located at the angles of a polygon which measures seven and one-half miles on the meridian and six miles at right angles to it. They are so situated that they command the railways and important highways which approach the city from all directions. The general form of the forts is as shown on Pl. IV.

The north front is protected by forts I to IV inclusive. Fort I is near the left bank of the Rhine, between the Ill and the Rhine and three miles from the inner line. Being in low ground and protected by the Ill, it has wet ditches, without a caponier at the salient. Fort II is three miles from the inner line, and one and three-fourths miles from fort I. Being on high ground and liable to attack, it has dry ditches with complete ditch defenses. Fort III is three

and one-fourth miles from the inner line, and one and one-half miles from fort II. Being in a re-entrant angle between II and IV and protected by the Souffel, it is smaller than the adjacent works. Fort IV is three and three-fourth miles from the inner line and less than a mile from fort III. It is on the northern extremity of the important ridge northwest of the city, and occupies a commanding position behind the Souffel. Being a salient it is a strong work.

The west front is protected by forts IV to VIII. Fort V is three miles from the inner line and one mile from fort IV. It is a strong work which occupies the most commanding position on the Hausberg ridge, and has good command over all the country in its front. Fort VI is three miles from the inner line and one mile from fort V. It is a strong work which occupies the southern end of the Hausberg ridge. The three forts IV, V and VI may be considered as the key point of the defense, as attack along any other line would not give the besieger a decisive victory or the possesion of a point from which he could successfully attack the inner line. Fort VII is two and one-half miles from the inner line and one and three-fourth miles from fort VI. It is a strong work which closes the gap between fort VI and the Bruche canal and creek. Fort VIII is two and three-fourth miles from the inner line and two and one-fourth miles from fort VII. It is a strong work which commands the plateau between the Bruche and the Ill, and the lines of communication which cross it.

The south front is protected by forts VIII to XI. Fort IX is three and three-fourth miles from the inner line and two and three-fourth miles from fort VIII. Being built in a swamp it is similar to fort I and has wet ditches without ditch defenses. Fort X is four and one-fourth miles from the inner line and two miles from fort IX. Like fort IX it has wet ditches without ditch defenses. Fort XI is five miles from the inner line and two and one-half miles from fort X. It is similar to forts IX and X being constructed on marshy ground along the banks of the Rhine. This fort is placed far from the inner line because of a heavy

wood extending along the Rhine in its rear; it was deemed advisable to advance it beyond the wood.

The works on the south front are not so important as those on the north and west, as a belt of country over one mile wide between the Ill and the Rhine can be inundated. This inundation is just outside the inner line of defense.

The east front is defended by forts XII, XIII, and XIV on the east bank of the Rhine, and two small forts near the east abutment of the railway bridge. Fort XII is three and three-fourth miles from the inner line and four and three-fourths from fort XI. Being in a marshy position it has wet ditches which are flanked by a small ravelin at the salient and half caponiers and scarp galleries. Fort XIII is three miles from the inner line and two miles from fort XII. It is similar in construction to that fort. Fort XIV is two and three-fourth miles from the inner line, two miles from fort XIII and three and one-half miles from fort I. It is similar to forts XII and XIII.

As an accessory to the outer line of defense, there is the strategic railway connecting the principal forts. This road leaves the Molsheim line behind fort VIII and joins the Germersheim line after passing about one-third of a mile in rear of all the forts of the sector between the Bruche and the lower Ill. Another line leaves the Bâle line near fort IX and connects with the canal from the Rhone to the Rhine near fort X. The communication thus formed parallel to the outer line of defense, with the numerous highways and railways that radiate from the city, indicate that the Germans have considered with great care the necessity of lines of communication between the inner and outer line of defense.

Inner Line.—The exact date of the original construction of the inner line of Strasburg is unknown; about the middle of the 16th century it was reconstructed by the German engineer Speckle, and was remodelled by Vauban when the city was taken by the French in 1681. The interior line had its longer dimension east and west; and its east end terminated in a strong citadel. The line was

composed of bastion fronts well supplied with outworks. To allow for the growth of the city, the Germans removed the entire northern and western fronts and constructed new ones much farther out. The old south front still remains as constructed by the French.

The new trace (Pl. V) starts from the Ill, at a point to the south of the city, forms a semicircle with its convexity turned to the northwest and returns to the Ill at a point north of the city. It then crosses the Ill, makes a turn on the right bank and extends to the canal from the Marne to the Rhine, which it follows for five hundred feet to envelop a park called the Orangerie. It then turns sharply to the south and follows the left bank of the lesser branch of the Rhine to the old citadel, which has been preserved. Throughout the west and northwestern part the trace is polygonal with armored caponiers protected by ravelins; in the north the inner line is simply a parapet covered by a wide wet ditch. The old citadel, included in the new inner line, is only a strong point of the line, and can hardly be depended upon as a keep in case of attack.

Résumé.—Strasburg is an example of intrenched camp constructed in accordance with the views of military engineers in Germany after the Franco-Prussian war. The site being nearly level, the distances between the forts and the main work were made to depend upon the range of the existing artillery and the tactical considerations governing attack and defense. It is probable that the works have been somewhat modified since the introduction of shells containing high explosives; the caponiers attached to the scarp have been replaced by counterscarp galleries, the roofs of all casemates and bomb-proofs have been strengthened, at least one-half of the guns from the forts have been removed to annexed batteries, and a few turrets have been constructed for rapid fire and 15 c. m. guns.

If threatened by an attack, the garrison of Strasburg would probably be at least 20,000 men; its armament would comprise about 450 heavy, and 200 light pieces besides those used to flank the ditches. In time of war the per-

manent defenses would be supplemented by field works and trenches connecting the detached forts and extending the zone of operations a mile or so to the front of the works.

At the time of the Franco-German war there were no detached forts, and although both the garrison and the defense were in a bad condition, the Germans after failing to reduce the place by bombardment were compelled to resort to a regular siege. The city was not surrendered until the assailants had made a breach in the main work and were ready for the final assault.

Barrier Forts.—The barrier forts constructed between 1870 and 1880, especially on the eastern frontier of France, do not differ materially from the detached forts of intrenched camps. As a rule they belong to the type of forts with a central cavalier.

CHAPTER IV.

LAND DEFENSES SINCE 1880.

The development of siege mortars and howitzers which began about 1869 had made such progress by 1880, that serious doubts began to be expressed as to the value of open defenses. In experiments conducted at Meppin in 1882 with a 21 c. m. siege mortar, fifty per cent of the shots were placed in a rectangle 1.5 x 13 yards at a range of 1000 yards, in a rectangle 4 x 26 yards at a range of 2200 yards, and in a rectangle 7 x 40 yards at a range of two miles. At a range of about one mile, five shrapnel shots produced 1439 hits in a horizontal target 109 yards wide and 164 yards deep.

From these and similar experiments it became evident that the barbette guns of the works constructed between 1870 and 1880, could not be manned after the assailant established his mortar batteries within effective range of the forts.

This was followed by the use of high explosives in shells, or the introduction of torpedo shells, between 1883 and 1885. The first authentic accounts of their effects were published in 1886; the results of experiments made at Malmaison, France, with 21 c. m. mortars containing 70 pounds of melinite. One shot struck a masonry caponier whose walls were 3.5 feet thick and whose arches were covered with 10 feet of earth. The shot penetrated and almost destroyed it. A second shot destroyed an arched ammunition chamber covered by 4 feet of masonry and 13 feet of earth. A third shot penetrated the covered way just in front of the counterscarp wall and blew down 40 feet of that wall. This fort was constructed of ordinary brick-work such as

was used in most of the continental fortifications.

The introduction of the mortar shrapnel and torpedo shell made it necessary either to protect the guns by armor, or to remove them wholly from the works. The latter solution was generally adopted in Germany and France; they were mounted in the intervals, generally in annexed batteries close to, and under the protection of the forts. The latter became infantry redouts. It also became necessary to remove or strengthen the caponiers, detached scarp walls, and bomb-proofs. The caponiers were generally removed and replaced by counterscarp galleries, the detached scarp walls were replaced by iron fences or barriers, and the bomb-proofs were strengthened. Experiments having shown that a bed of Portland cement concrete 5 feet thick would resist the penetration of single mortar shells, this concrete was used to reinforce the arches and walls previously constructed. In new works, concrete was the only material used in the construction of masonry. Experiments also indicated that a covering of earth less than sixteen feet, acting as a tamping, increased the effects of explosion; a thickness of three feet however added little to the explosive effect and prevented the scattering of splinters which would result from the projectile striking a bare wall.

Armored Forts.—General Brialmont of the Belgian engineers was of the opinion that artillery could no longer be maintained in open batteries either within, or without, the works. He therefore advocated securing the desired protection for the artillery, by placing it in armored turrets, or behind armored shields. In the year 1882 the Roumanian government decided to fortify its capital, Bucharest, and engaged General Brialmont to design its defenses. The first extensive use of armor, was made in these works. The system adopted by General Brialmont is now known as that of *armored forts.*

Fort with Keep.—Pl. VI. This is of the general form of the German fort, although deeper, and has about the same development of front. The profile and trace show a

dry ditch 20 yards wide with an earthen scarp and counterscarp, an iron barrier on the faces and flanks, and a masonry scarp along the gorge. The ditch is swept from a caponier at the salient angle, two caponiers at the shoulder angles and two scarp galleries in the flanks of the gorge. The ditch of the keep has masonry scarps and counterscarps swept from counterscarp and scarp galleries. The parapets on the faces and flanks have a minimum thickness of 20 yards, and on the gorge 5 yards. The command varies from 32 feet along the faces to 23 feet along the gorge. The principal armament consists of six 15 c. m. guns in three turrets, one near each shoulder angle and one in the keep; two 21 c. m. howitzers under shields, one on each face; one 12 c. m. howitzer under a shield in the salient; six 5.3 c. m. rapid fire guns in disappearing turrets, four at the four angles of the main work and two in the keep. Besides these, barbettes are arranged for field guns on the faces and flanks, and an infantry parapet along the gorge and along such parts of the faces and flanks as are not occupied by artillery. Before the works had been actually begun, the effect of torpedo shells was ascertained, and to resist their destructive effects, all arches exposed to curved and vertical fire were made of concrete six to eight feet thick. Otherwise the underground constructions are similar to the German fort. The keep in this work forms the second line of defense; most engineers differ from General Brialmont and consider the keep of little value as compared to its cost.

Fort Without a Keep.—The other forts of the defensive line are quadrilaterals of the type shown in Pl. VIII, Fig. 1. The front of this work is only 110 yards and the depth 80 yards. It has a ditch 9 yards wide with a masonry scarp along the curtain of the gorge. The ditch is flanked by fire from counterscarp galleries and disappearing turrets. The command of the work is only 13 feet and the thickness of the exposed parapets 26 feet. The armament consists of four 15 c. m. guns in two turrets on a central traverse parallel to the face; two 21 c. m. howitzers under shields

along the same line of the work, and four 5.3 c. m. rapid fire guns in disappearing turrets at the four angles of the work. The faces, flanks, and gorge are also provided with an infantry parapet.

Fortins.—Besides the main forts there have been recently constructed by the Roumanian engineers an equal number of smaller forts or "fortins" for the defense of the intervals. These are generally triangular works with faces each 130 yards and salient angles of 107 degrees. The type is shown in Pl. VII, Fig. 2. The work is surrounded by a ditch 10 yards wide with a masonry scarp along the curtain; the ditch is swept by fire from counterscarp and scarp galleries. The command is about 12 feet and the thickness of parapet 26 feet. The armament consists of one 12 c. m. gun in a turret in the centre of the work, two 21 c. m. howitzers under shields in the gorge to sweep the interval between the works, and three 5.3 c. m. rapid fire guns in disappearing turrets at the salients. The work does not seem to be well protected against capture by open assault.

The line of defense at Bucharest numbers 36 large and small forts; it has a development of forty miles and a radius of about six and one-half miles. The total armament numbers eighty-six 15 c. m. guns in turrets, eighteen 12 c. m. guns in turrets, seventy-four 21 c. m. howitzers under shields, one hundred and twenty-seven 5.3 c. m. guns in disappearing turrets, and four hundred and seventy-six machine or rapid fire flanking guns in casemates. General Brialmont also designed an inner line for this fortress, but it has not yet been constructed.

In 1888 General Brialmont was commissioned to design the new defenses of the river Meuse in Belgium which consist of twelve forts around Liege and nine around Namur. The general type of these works according to General Brialmont is as shown in Pl. VIII. The shape of the work is that of an equilateral triangle, because it requires the minimum number of ditch defenses. The centre of the work is a concrete mound in which are constructed the bomb-proofs of the work. The armament consists of two

15 c. m. guns, four 12 c. m. guns, two 21 c. m. howitzers, two rapid fire 12 c. m. howitzers, four 5.7 c. m. rapid fire guns all in turrets or under shields. One side of the gorge shows a casemate battery for sweeping the interval between the forts. Though the type given is triangular, no fixed rule was adopted, and some of the works were made with more sides when the features of the site required it. The armor used by General Brialmont was in the form of turrets and shields.

Turret for two 15 c. m. 25-Calibre Guns.—In 1885 experiments were made in Roumania to test two types of turrets, one of a mushroom form and the other of a cylindrical form, which had been purchased by the Roumanian Government. As a result the mushroom type turret shown in Pl. IX was adopted. As manufactured by the Gruson works of Germany, the armored top of the turret consists of three plates of 7.8 inch rolled wrought iron screwed to a skin consisting of two thin plates of steel riveted together. The armor is carried by a cylinder of plates and angles about 16 feet in diameter and 8 feet high. The cylinder rests upon a horizontal circular plate; this is supported by a ring of small steel conical rollers which run on a circular track. The glacis is made of a number of voussoirs of chilled cast iron set in concrete. The entire turret is set in masonry, in which are formed the magazine, loading rooms, etc. The total weight of the turret without guns is 248 short tons, or with its guns about 251 tons.

The service of the guns and turret requires one officer, one gunner, and four men to serve the guns, two men to bring up ammunition, and four men to revolve the turret. A complete revolution can be made in one minute and the elevation of the guns changed one degree in three seconds.

At Bucharest this turret was exposed to the fire of three 15 c. m. guns at a range of 1100 yards and received 36 hits without serious injury. One hundred and sixty-five rounds were fired at it from two 21 c. m. rifled mortars at a range of 2700 yards without hitting it. The turret

then received 33 more shots with reduced charges from the 15 c. m. gun at a range of only 60 yards, and although very much damaged it was declared still serviceable to protect its guns and interior mechanism. After one day's repairs the guns were mounted and the turret was found to revolve with ease. This armored turret may, therefore, be considered as proof against ordinary heavy siege artillery. Similar turrets are now made in Germany of chilled cast iron, and in France and Belgium of wrought iron and steel. A smaller turret of the same type is also made for 12 c. m. (4.72 inch) guns. The gun carriages are of two classes; the *minimum-port* as shown in Pl. IX, and the *non-recoil*, in which the recoil is communicated to the turret by a muzzle ring on the gun. In those made for the defenses of the Meuse it was specified that the muzzle of the guns must not project outside the turrets. Turrets are also made for single guns as these are preferred by some artillerymen.

Shield for 21 c. m. Howitzer.—The shield for the 21 c. m. howitzer is as shown in Pl. X. The construction of the overhead shield and glacis does not differ materially from the roof and glacis of the turret. The shield is connected by angle irons to two steel transoms *a*, which act as the checks of the gun carriage and are united by a cross transom, *b*. The transom, *b*, rests upon a vertical shaft, *c*. The recoil of the howitzer is communicated by the transoms and angle irons to the shield which ordinarily rests directly upon the glacis armor. A simple device allows the weight of the gun and shield to be transferred to the shaft when the gun is to be traversed. The motion of revolution is given by a pair of levers or a ratchet wheel. The service of the howitzer and turret requires four men to serve the howitzer and rotate the turret, and two men to raise and lower the shaft. The total height of the chamber is about 16.0 feet and its diameter 13.5 feet. Similar shields are constructed for the ordinary 15 c. m., and the 12 c. m. rapid fire howitzers.

Disappearing Turrets.—A disappearing turret as manufactured for the 5.3 or 5.7 c. m. rapid fire gun, is as shown in Pl. X. The overhead shield and glacis armor are constructed as in the turret and howitzer shield, but of less resisting power. The shield rests on a low cylinder of cast steel plate. The weight of the whole is transmitted to the central shaft by means of two strong transoms as in the howitzer turret. The shaft itself rests on a counterpoised lever by means of which it is raised and lowered. The gun is supported on horizontal rails which allow it to be withdrawn into the turret when the latter is to be lowered. The service of the gun and turret requires only two men. The total weight to be lifted is about 12 short tons.

Armored Fronts.—Lieutenant Colonel Schumann of the German Engineers, who devised the turrets and shields manufactured by the Gruson comyany, about 1885-87, originated a system of fortification which has been styled the system of *armored fronts*. This system has been adopted by the Roumanian Government for the defense of three places, Foksani, Nemolassa, and Galatz on what is known as the Sereth line of defense against invasion from the north-east.

The guiding principles of Schumann's sytem were to avoid the great intervals between works of the prevailing systems, and to provide a maximum amount of fire from small calibre guns. His works were all simple batteries open at the gorge arranged in two or three lines. At Foksani the arrangement is in three lines; the first line has forty-one works; the second and third each fifteen. The interval between the works of the first line is about 500 yards, and of the others a little less than ~~one-third~~ three times this distance. The distances between the lines is approximately 500 yards. In the first line, the works are barbette batteries of seven 3.7 c. m. (1.5 inch) rapid fire guns in transportable turrets (Pl. XI, Fig. 1). The second line consists of six 5.3 c. m. in disappearing turrets, one 12 c. m. gun in a disappearing turret, and two 12 c. m. mortars, (Pl. XI,

Fig. 2). In each work of the third line there is one 12 c. m. howitzer and four to six 5.3 c. m. guns. (Pl. XI, Fig. 3). The profile employed in the construction of the batteries is the triangular profile with shallow ditches, planted with thorny bushes twisted with wire, or filled with wire entanglements. (Pl. XI, Fig. 4).

Transportable Turrets.—The transportable turret invented by Lieutenant Colonel Schumann is shown in Pl. XIII; the roof is of cast steel 1.5 inches thick which makes it proof against small arms and shrapnel. The total weight of the turret with its gun is from 2.2 to 2.5 tons, depending on the calibre of the gun. These turrets are manufactured for the 3.7 c. m., the 5.3 c. m., and the 5.7 c. m. rapid fire gun.

Mortar Shield.—The mortar shield is shown in Pl. XII. It consists of a breech loading mortar buried in a spherical steel casting which is supported on a revolving vertical shaft.

The objections to Schumann's system of defense are that it divides the defenders into a great number of small squads not easily controlled, and that it leaves no sphere of action for infantry cooperation or active defense.

Works for Near and Distant Defense.—Besides the systems of great armored forts of General Brialmont, and of armored fronts of Colonel Schumann, there is a third system of defensive works favored by engineers who do not believe in such an elaborate use of armor on account of its cost.*

It is known as the system of *near and distant defense.* These engineers recognize that guns cannot be kept mounted in barbette in a fort when the besieger once opens fire with his howitzers and mortars, but they do believe that the heavy guns can be kept in barbette or embrasure batteries in the interval between the points of support if concealed by the folds of the ground, hedges, or other masks. They believe that the works upon the points of support should

* The cost of the defense of the Meuse, including the purchase of land was over $14,000,000.

be mainly for infantry and movable guns; if, however, the location is one that commands the surroundings and has no other good site in the vicinity, one or two large guns may be placed in the work either permanently in turrets, or temporarily in barbette to act simply against the line of investment, and to be withdrawn when the siege is begun. A few rapid fire guns in disappearing turrets are allowed in the redouts to assist in the near defense. In this system the intervals between the works, about one to one and one-fourth miles, are usually swept by the fire of howitzers in masked batteries at the gorge of each near-defense redout.

Near-Defense Works.—The simplest redout of this kind is the type adopted in the British service, Pl. XIII, known as a semi-permanent infantry redout. The trace of the interior crest approximates to a rectangle with rounded ends whose extreme width is 93 yards and extreme depth 40 yards. The triangular profile is employed and the work is protected from assault by an iron barrier and wire entanglement which extends entirely around the work. Under a central traverse are bomb-proofs for the troops who ordinarily camp outside the work; these bomb-proofs have a covered communication to the parapets of the faces. The parapets have a low command and are designed to protect the men in their rear from shrapnel fire. The infantry defense is strengthened by two rapid fire guns in disappearing turrets. In very important places both the size of the work and the number of disappearing turrets are increased.

On the continent, these redouts usually have masked casemate batteries similar to caponiers in the gorge. These are known as "traditor" batteries, and replace the guns in the flank for sweeping the intervals between the works. The principles governing their field of fire as designed by Colonel Voorduin of the Dutch army, are as shown in Pl. I, Fig. 7. The forts are small redouts placed at intervals of 2200 yards and have an artillery armament of two 12 c. m. guns in a turret for front defense and distant fire, six

smaller guns or howitzers in the "traditor" battery along the gorge for flanking adjacent works and the intervals. These "traditor" batteries are entirely masked by the work, from the view of the enemy in the angle of front fire. For near defense the infantry is assisted by rapid fire and machine guns in barbette. The work is protected from assault by a wet ditch and wire entanglement and, as the turret gun is used only for distant fire, it is concealed from the besieger in the foreground by the parapet in front.

In Russia the supporting points are occupied by closed redouts of large dimensions with well flanked ditches of triangular profile. These works admit of individual defense by infantry and by movable rapid fire and machine guns. The intervals are swept by "traditor" batteries. As no turrets are used, the heavy artillery armament is in open batteries constructed in the intervals. In Germany, Austria, and France, the forts in existence have been converted into near-defense works for infantry and machine guns, proof against modern siege artillery, by replacing the caponiers by counterscarp galleries, and by removing most of the heavy guns into annexed batteries outside, but under the protection of the redouts. Usually one or two of the heavy guns are left in the work but are placed in turrets.

The latest designs of military engineers show a preference for closed redouts with a triangular profile, containing one turret for heavy guns and several disappearing turrets for the machine guns, with "traditor" batteries sweeping the intervals. All the works contain ample bomb-proof quarters, magazines, and communications for the artillery and infantry garrisons, and differ only in the minor details of the number of guns, shapes of works, and manner of constructing the casemates.

Distant-Defense Works.—These are batteries for guns, howitzers, and mortars. The guns usually employ direct and the other pieces indirect fire. For direct fire the guns may be either in fixed, or in movable, emplacements. Fixed emplacements are batteries laid out and constructed in time of peace. As an enemy could soon silence a fixed

battery whose location was known, care is taken to conceal this location as much as possible, by the irregularities of the site, or by natural and artificial masks, and to distribute the armament as much as possible by placing only two or three guns in each battery. Disappearing gun-carriages are employed for the same purpose. Pl. XIV, shows the type of a two gun battery employed in the British service. To protect this battery from capture by open assault, it is placed several hundred yards in rear of the line of redouts, and, if not safely guarded by infantry, is surrounded by a wire entanglement. Guns in movable emplacements are guns on flat cars which move on a railway in rear of the line of redouts; such a mounting has been constructed in France [Pl. I, Fig. 6]. It would be impossible to silence a gun thus mounted except by a chance shot.

Howitzer and mortar batteries are concealed by the folds of the ground which, while they do not interfere with curved and vertical fire, allow the construction of observatories near by, for observing the effect of the shots.

Barrier Forts.—A barrier fort must be safe against capture by open assault or bombardment, its guns must be mounted so that they cannot be easily silenced, and the work must have an ample water supply and bomb-proof magazines for provisions and ammunition, so that the work cannot be taken by investment during the ordinary duration of a war. These conditions require that the work be surrounded by an obstacle in the shape of a deep, wide ditch thoroughly flanked by the fire of machine or rapid fire guns, that all guns be protected by armor, and that ample bomb-proofs be provided for troops and supplies.

Two barrier forts have been constructed recently by the Germans at Molsheim, in the foot hills of the Vosges mountains, about 12 miles west of Strasburg; where the only north and south railway in Alsace west of Strasburg, connects with an east and west line running from the French boundary to that city. The works are of the same general character as those in the defenses of the Meuse,

and are armed with four 15 c. m. howitzers and six 5.7 c. m. rapid fire guns all protected by armor.

The particular features of each barrier fort depend upon the site; this may allow the use of casemate batteries when the valley to be swept is narrow, or allow the omission of the ditch when the site is an isolated rock, which may be converted into a steep scarp, as the site of Fort Bard.

Accessory Defense.—Besides the line of forts and the continuous line, an intrenched camp is provided with a system of railways and highways, electric lines, search lights, observatories, and if the location permits of it, a system of inundations.

Railways.—The railway system consists of concentric and radial lines connecting the various forts with depots of general supply and the inner line; unless the natural features of the site conceal it, this line should be either sunken, or be concealed by a mask of trees. It is usual to construct the concentric line some distance in rear of the forts with a switch running to each work. Highways are constructed so as to provide a good system of communication for the tactical movement of the troops; whenever these highways lead to the front of any batteries or works, they are so directed that they can be easily enfiladed from the rear, and thus rendered useless to the enemy. Electric lines in underground conduits are laid for telephones or telegraph instruments leading from the different works to the headquarters of the defense, and to the camps of the mobile garrison. Electric light wires in underground conduits run from the various forts to the central power station of the city itself, which is out of range of the enemy's fire. Armored observatories and search lights are constructed in the forts on the fronts of attack. The former consist simply of a rotating shield similar to the howitzer shield, and the latter are mounted in disappearing turrets similar to, but smaller than, those used for rapid fire guns. Inundations are very valuable accessory defenses as they render both mining and sapping impossible, and thus lessen the

front over which the assailant can make an attack. These can be utilized only when a stream runs into, or parallel to, the front of some part of the line of defense so that the dams may be kept under the protection of the forts.

CHAPTER V.

PRINCIPLES OF LAND DEFENSE ILLUSTRATED BY THE FORTIFICATIONS OF FRANCE ON THE GERMAN FRONTIER.

The selection of the points to be fortified is made by the military authorities of a nation, and conforms to the general scheme of defense, or to the plan of operations of the land forces to resist invasion either by offensive or defensive measures. In some countries there is a permanent commission for this purpose designated the Commission of National Defense.

Scheme of Defense.—The scheme of defense, which determines the location and character of each permanent fortification depends upon the organization and efficiency of the armies of the defender and probable assailant, as well as their allies; the configuration of the boundary; the topography of the boundary and adjacent territory; the location of the existing and projected lines of transport and supply; and the location of the political and commercial centres of the country.

Armies.—Nearly every continental power of Europe has now adopted the system of universal service, and every able bodied man is enrolled either in the active army, or in one of its reserves. The military strength of a nation has, therefore, become approximately proportional to its population. In the future a small nation without allies can no longer meet a large one in the open field, but must resort to fortification to strengthen its forces in the future struggle for national existence. The fortifications must be permanent, for each great nation now maintains so large a standing army that a small one would be overwhelmed be-

fore she had time to organize an adequate system of field defenses. This accounts for the permanent works constructed since the Franco-German war by the small states of Europe, Belgium, Holland, Denmark, Roumania, and Switzerland, which no longer trust wholly to guaranteed neutrality and doubtful alliances.

The great nations maintain in their peace establishments only a fraction of their available men, therefore, it will take time to mobilize their armies and transport them to the threatened frontier. During this time every available railway will be worked to its utmost capacity by the military authorities, and any interference by the enemy would be more or less disastrous. To prevent this interference it is usual to construct a line of fortification, or a great intrenched camp, near the frontier which may be used as a base against an invader's raiding parties. Under existing conditions a nation can only neglect those frontiers which separate it from nations which are weak, or which are certain to be either friendly or neutral.

Boundary.—The form of boundary which separates a country from its possible or probable adversaries has an important bearing upon the plan of invasion, and therefore upon the scheme of defense. If the boundary be approximately a right line, its form gives no advantage to either side; it is otherwise, however, if the boundary forms a salient or re-entrant angle. If we consider a possible war between Russia and the allied powers of Germany and Austria, it is probable that the allied armies would be first mobilized, and would have the option of invading Poland from the south and west, north and west, or from the north, south, and west so as to cut off and destroy the Russian army which now occupies that province with headquarters at Warsaw. To meet this contingency, Russia must either withdraw her army and temporarily abandon Poland, or she must protect this army in an intrenched region until her other armies can advance to the support of its flanks, and compel the retreat of the armies which threaten its communications. A war between Russia and

Germany would place the German force in East Prussia in the same predicament.

Topography.—If the boundary be a range of high mountains with few passes, as the Alps in Europe, an invader may be checked temporarily by the construction of strong works in these passes; if the boundary be a wide, deep river, with few bridges, strong works commanding the bridges will have the same effect. If the mountain chain, or river be somewhat removed from the boundary, but is generally parallel to it, as the Carpathian Mountains of Austria, and the Rhine river of Germany, by fortification at the passes and bridges, these obstacles may be converted into lines of defense and bases for offensive movements. If the mountain chain or river be perpendicular instead of parallel to the boundary, the fortifications convert it into a screen, from which offensive movements may be made against an invader who advances on either side, parallel to it.

Lines of Transport.—Modern armies on account of their great size, require the use of all railways in their rear for their maintenance and supply. Invasion along any line of railway may be interrupted by the construction of a fortification to guard some important bridge, tunnel, or junction where the route cannot be easily diverted.

Political and Commercial Centres.—While it is true that the defending army, and not its capital, must be the true objective of the invading force it is equally true that any interruption of the machinery of government will seriously embarass the defender. Unless the political capital is secure against ordinary attack, the defending army will, in its retreat, endeavor to interpose itself between the invader and that capital, and may thus be seriously embarassed in its movements. For this reason it is usual to surround the capital with permanent fortifications, particularly if this capital be near a dangerous frontier. In some countries, the political capital being so located as to be difficult to defend by the armed strength of the state, a commercial centre is selected and fortified with a view to

its use as the political capital in time of war. Antwerp is the intrenched camp of Belgium, instead of Brussels, because being a sea-port, it is less easily invested by a land force, and is more easily relieved by friendly powers.

THE FORTIFICATIONS OF FRANCE ON THE GERMAN FRONTIER.

Boundary.—[Pl. XI.] The common boundary of France and Germany, as fixed by the treaty of peace after the Franco-German war, begins on the Swiss frontier about twenty-five miles west of the Rhine river, thence runs almost parallel to the Rhine, to a point thirty miles west of Strasburg; thence it runs in a northwesterly direction to a point about eight miles west of the Moselle at Metz; thence it runs northward to the Luxemburg frontier. The total length of this boundary is one hundred and seventy miles, of which only fifty miles follows a natural barrier; viz.—the crest of the Vosges mountains north of Belfort. The railways which cross the frontier and connect Paris with the Rhine are 1st. Paris—Laon or Reims—Mezieres—Diedenhofen (Thionville)—Treves—Cologne or Coblentz. 2d. Paris—Reims—Verdun—Metz—Mayence or Germersheim. 3d. Paris—Nancy—Strasburg. 4th. Paris—Langres—Belfort—Mulhausen. While no railways cross the Vosges mountain boundary, there are several branch lines which reach the foot hills on either side; their termini are connected by good highways. The principal railways, parallel to the frontier, are those following the valleys of the Meuse and Moselle. National highways follow the lines of all the great railways; departmental and smaller highways form a complete network of good lines of communication perpendicular, and parallel, to the frontier. The frontier rivers, the Moselle and the Meuse, both run parallel to the boundary; neither can be considered a serious obstacle, as they are not navigable above the Verdun—Metz railway. West of the Verdun valley is the great basin of the Seine, in which all its tributaries flow toward Paris, and thus form natural lines of invasion. South of the sources of

the Moselle and Meuse is the basin of the Saône, one of the great tributaries of the Rhone. East of the boundary is the German intrenched camp of Metz and the great military base of the Rhine, protected by its numerous fortified bridge heads, Cologne, Coblentz, Mayence, Germersheim, Strasburg and Brisach. It is thirty miles from the Upper Rhine to the frontier south of Strasburg, and from thirty to one hundred and twenty miles from the Rhine to the frontier between Strasburg and Coblentz. From Metz to Paris is only one hundred and seventy-five miles.

The Franco-German war, which deprived France of the Rhine as a boundary above Strasburg, and of her principal eastern fortifications, Metz and Strasburg, placed her in a very disadvantageous position to defend her territory should another war break out before her military system was wholly reorganized. Even with an equal land force the defensive line, and offensive base of the Rhine would give Germany a great advantage in any future war. To restore the equilibrium between the two powers, France, immediately after that war, adopted the universal service system in her army and began to fortify her new frontier.

The war demonstrated that the old fortification with outworks and advanced works, no longer protected the cities about which they were built; many of the old fortified cities were therefore wholly abandoned by the military authorities. As the intrenched camps of Metz and Paris were taken by investment alone, the fortification of the new lines were so enlarged or combined as to make a complete investment almost impossible.

Lines of Defense.—Assuming that Paris would be the ultimate objective of any invasion, it was decided to organize the defense in three lines; a frontier line which would check invasion and cover the mobilization, assembly, and first deployment of the field army; an intermediate line which would cover the assembly of the territorial troops and afford a refuge to the field armies should they be compelled to retreat; a strong line about the city of Parish which, on account of its social and

political value, was to be the citadel of the defense as in former wars.

Frontier Line.—As previously stated the only natural lines of defense, on or near the frontier, are the Vosges mountains, the Moselle, and the Meuse rivers. As the German army can assemble in Lorraine west of the range of the Vosges, a line along this range could be readily turned and would soon be untenable. The Moselle too runs into German territory and in itself offers no secure position for the left flank north of Toul. The Meuse forms a good line north of Toul, but is too far distant from the boundary south of that place. After careful examination a line was adopted which combined the best features of each of these lines. This line begins on the north at the Belgian frontier and follows the Meuse to Toul, thence along the Moselle to its headwaters in the Vosges mountains. The right flank is prolonged to the Swiss frontier, via Belfort and Montbeliard as will be explained hereafter. The line is nowhere more than forty, nor less than twenty miles from the boundary and therefore leaves but a narrow belt of country without protection.

To fortify this entire line, one hundred and sixty miles long, would not be advisable either from a military, or from a financial point of view; hence the French Committee of National Defense divided it into four intervals, two of which are fortified so as to leave no road unguarded, and two of which offer little or no obstruction to the passage of an enemy. The fortified intervals are called curtains, and extend from Verdun to Toul, and from Epinal to the Swiss frontier.

The northern interval, fifteen miles in extent, between Verdun and Belgium, is left open because the communications in this section lead away from the objective, and because a hostile army operating in this narrow space, with a neutral territory on the one flank, would be in a dangerous situation. On the railway near the Belgian frontier the old fortified place of Montmédy is left as a temporary barrier fort.

On the east bank of the Meuse, extending from Toul northward beyond Verdun, is a high plateau from three to six miles wide called the "Côtes de Meuse." The northern curtain, fifty miles long, follows this ridge. Its left flank is formed by Verdun, an intrenched camp consisting of fourteen forts, an inner line, and a citadel; the perimeter of the exterior line measures twenty-five miles. Its right flank is formed by Toul, an intrenched camp consisting of eight forts and an inner line; the perimeter of the exterior line measures twenty-two miles. The connecting curtain, thirty-four miles long, is formed of six barrier forts and one battery so located that they command every important highway which crosses the ridge, and also protect the railway in the Meuse valley. As the flanks of the curtains are separated by a two days' march, an army attempting to turn both flanks simultaneously would find its wings beyond supporting distance of each other.

The third interval, between Toul and Langres, thirty-seven miles in extent, is occupied by three barrier forts; one on the Moselle at Pont St. Vincent, six miles from the exterior line of Toul, and two on the Meuse. One of the forts on the Meuse is six miles from Toul, and the other commands the railway junction at Neufchateau. In advance of this line are barrier forts commanding the railway junction north of Nancy, and the Strasburg railway near the frontier.

The southern curtain begins at Epinal, an intrenched camp consisting of eight forts, without an inner line; the perimeter measures nearly twenty-five miles. From Epinal to the headwaters of the Moselle in the Vosges mountains, a distance of thirty-one miles, are five barrier forts on the west bank of the Moselle, commanding all the lateral valleys entering from the east. Between the Vosges and the Jura mountains is a wide valley, known as the "Trouée de Belfort," through which pass the railways and highways connecting Paris and Lyons with the upper Rhine. The centre of defense of this valley is the intrenched camp of Belfort which consists of an exterior line of nine forts con-

nected by curtains, and a citadel; the perimeter of the outer line measures twenty-four miles. One barrier fort to the north closes the gap between the Vosges mountains and Belfort, and five barrier forts close the gap between Belfort and the Swiss frontier, about nineteen miles distant. The French armies, assembled behind these curtains and the Belgian frontier, will be in a good position to act offensively against the flanks of any hostile armies which attempt to penetrate the intervals. If the French field armies invade foreign territory the reserves would occupy these curtains and transform them into a secure base.

Intermediate Line.—If a hostile army succeeds in passing the frontier line of defense, it will find itself in the basin of the Seine, and will naturally follow down one of the numerous tributaries which lead in the direction of Paris. In the north, these are the Oise, the Aisne, and the Marne. To check an advancing hostile army, the great plateau between the Oise, the Aisne, and the La Fère-Laon-Reims railway has been converted into an intrenched region. An intrenched camp at La Fère is connected with the Aisne, eighteen miles distant, by five barrier forts constructed near the eastern edge of the plateau. La Fere is a double bridge head of eight forts and an inner line; the perimeter measures twenty-four miles. Between the Aisne and the Marne is the intrenched camp of Reims consisting of ten forts and several batteries without an inner line; the perimeter measures forty-five miles. The northern forts are six miles from the Aisne, and the southern, seven miles from the Marne. A great forest occupies the space between Reims and the Marne. A barrier fort commands the defile of Epinal through which passes the Paris-Strasburg railway, the Marne, and a national highway.

In the south the tributaries of the Seine are the Aube, the Upper Seine, the Armançon and the Yonne. A hostile army, which passes the southern curtain will reach these rivers as well as the valley of the Rhone, by passing through the triangular territory limited by Langres, Besançon, and Dijon. This territory has been converted

into an intrenched region by making the three vertices intrenched camps. Langres has nine exterior forts, four intermediate forts, and a citadel; the perimeter of the exterior line measures thirty-three miles; its forts command all the railways in the vicinity. Besançon, fifty miles from Langres, has nine exterior forts, six intermediate forts, and an inner line; the perimeter of the exterior line measures twenty two miles, and forms a double bridge héad on the Doubs river. Dijon, on the Paris-Lyons railway, thirty-seven miles from Langres and forty-two miles from Besançon, has six exterior forts, one intermediate fort, and an inner line, the exterior perimeter measures twenty-four miles. A hostile army attempting to invest any of these places would find its rear threatened by the forces occupying the others as bases. This region has good railway and highway connections with Paris and the south of France.

Paris.—The intrenched camp of Paris has been enlarged since the Franco-German war by the addition of a new exterior line. At present it consists of an exterior line of works, consisting of three curtains on the perimeter of a polygon seventy-two miles long, and seven and one-half miles from the city. There are two undefended intervals of nine miles in this outer line, and one of nearly the same length occupied by the Seine. The outer line is made up of groups of forts, redouts, and batteries. An intermediate line of eighteen forts and several batteries extends around the city, about four and one-half miles in rear of the outer line. The city itself is surrounded by a continuous line of bastion fronts without outworks. To invest the present defences, as Paris and Metz were invested in 1870–71, would require an army of from 500,000 to 575,000 men.

The standing army of France consists of twenty corps, of which nineteen are in France, and one in Algeria. The home army is territorially distributed with corps headquarters at Lille, Amiens, Rouen, Le Mans, Orleans, Chalons, Besançon, Bourges, Tours, Rennes, Nantes,

Limoges, Clermont-Ferrand, Lyons, Marseilles, Montpellier, Toulouse, Bordeaux, and Nancy. The railway systems of France are adequate for the rapid transportation of the corps to the positions assigned them in the line of the defense.

The great defect of the defensive system of France, is that the garrisons of the numerous forts and intrenched camps will greatly diminish the strength of the field army and may seriously impair its usefulness. A defensive line like the Rhine river, consisting of a few strong bridge-heads connected by a wide, unfordable river, is in this respect very much superior to it.

CHAPTER VI.

SEA-COAST DEFENSE AND NAVAL ATTACK.

The purpose of sea-coast defense is to protect seaports, navy yards, arsenals, dock-yards, and coaling stations from bombardment, or from capture by a hostile navy; to secure harbors of refuge and naval rendezvous for friendly naval and merchant vessels; and to prevent the landing of a hostile army upon the coast for the purpose of invasion.

In a strategical sense, coast fortifications correspond to the land fortresses near the frontier, and form a line of resistance against invasion, and a base for the offensive operations of the navy. Permanent coast defenses are, as a rule, organized only to resist naval attack and assault by small landing parties; some of the important naval stations are, however, converted into intrenched camps equally secure against attack by sea and by land. The number of places which must be defended is much greater on the sea-coast, than upon the land frontiers. A hostile army occupies only such places as are on its lines of operation, and subjects to bombardment only such as are fortified and garrisoned. The hostile navy, on the contrary, is liable to enter any port where there is shipping worth destroying, whether fortified or not, and is liable to subject to bombardment or indemnity any sea-coast town. On the land frontiers, therefore, only cities of military value are fortified, while on the sea-coast every commercial port is fortified, whether it is of military and naval value or not.

The places to be fortified are usually determined by a Board or Committee, consisting of officers of both the Army and the Navy. A Board for this purpose was appointed

by the President of the United States in 1885 in accordance with an Act of Congress. This Board was composed of the Secretary of War, two officers of engineers and two of ordnance of the Army, two officers of the Navy, and two civilians; its duty was "to examine and report at what ports fortifications or other defenses are most urgently required, the character and kind of defenses best adapted for each, with reference to armament." The report of the Board was submitted in 1886; it gave a list of twenty-seven ports on the coasts and great lakes of the United States where fortifications were urgently required. The estimated cost of these defenses was $126,377,800.

Naval Vessels.—Naval vessels are divided into two classes—*armored* and *unarmored.* While all naval vessels are constructed primarily for naval combat, those of the first class, being to a certain extent protected against hostile artillery, are capable of attacking coast defenses. Unarmored vessels can attack defenseless ports only. The armored vessels of a navy are battleships, armored cruisers, and coast defense vessels.

Battleships.—Battleships are sea-going vessels which carry a heavy armament, and have their heavy guns and engines protected by thick armor. Plate XVI shows the general characteristics of a battleship, being a diagram of a ship of the type of the Massachusetts, Indiana, and Oregon of our own navy. The dimensions of these ships are, *length* 384 feet, *beam* 69 feet, *draft* 27 feet, and *displacement* about 10,000 tons. Their protection against direct fire lies in an armored belt, armored bulkheads, an armored citadel or casemate, armored turrets and shields, and an armored conning tower. In these ships the armor is steel. The *armor belts* extend along the water line, and are 7½ feet wide and 18 inches thick. As the ends of the ship are unarmored, to preserve the buoyancy of the vessel should these ends be destroyed, there is a steel *protective deck* 2¾ inches thick extending below the water line from the bulkheads to the bow and to the stern. A similar deck covers the inclosure formed by the armor belts and bulk-

heads, and protects the machinery of the vessel. The *armored citadel* is above the armor belt and is protected by armor 5 inches thick. The *turret emplacements* are made up of a fixed barbette foundation and a rotating turret. The *armored barbette* of the turret for the 13 inch guns rises from the protective deck and has a thickness of 17 inches; the *rotating armored turret* has a thickness of 15 inches. In the turrets for the 8 inch guns, the barbette is 10 inches thick, and the rotating turret 8 inches. The *shields* for the 6 inch guns are 6 inches thick. The *conning tower* for the commander of the vessel is protected by armor plate 12 inches thick. The only protection against mortar fire and aerial torpedoes lies in the protective and ordinary decks. The protection against submarine mines and submarine torpedoes lies in the cellular construction of the hull, and the division of the ship below the water line into water tight compartments. The hull is composed of two steel skins about 3½ feet apart connected by longitudinal and cross frames dividing the space into small cells. From the description, it is evident that a battleship is very much weaker to resist high angle fire and submarine attack, than it is to resist the direct fire of guns.

The heavy armament is made up of four 13 inch, and eight 8 inch guns, in turrets, and four 6 inch rapid fire guns, behind shields; the light armament consists of six 1 pound rapid fire guns, and four machine guns. Some of the small guns are mounted in the military tops of the masts, where they are protected from machine and small arms' fire, by a steel barbette. In the principal battleships now under construction the heavy armament consists of four 12 inch guns, and twelve 6 inch rapid fire guns; the light armament, of sixteen small rapid fire, and two or three machine guns.

Battleships are arranged in Brassey's Naval Annual of 1900, in three classes, according to their offensive and defensive value. Those of the first class are of recent construction, and have a displacement of from 10,000 to 15,000 tons. The Oregon type belongs to this class. Those of

the second class are either somewhat smaller, or were constructed before the adoption of the latest designs. We have no vessels belonging to this class. The third class is composed of the oldest vessels in service and those of recent construction whose displacement does not exceed 7,000 tons. The only vessel of this class in our navy is the Texas, whose displacement is about 6,300 tons, and whose heavy armament is made up of two 12 inch, six 6 inch, and twenty-two smaller guns.

Armored Cruisers.—Armored cruisers are sea-going vessels in which protection is sacrificed to secure speed. Pl. XVIII, Fig. 1 shows the characteristics of this class of vessels, being a diagram of the armored cruiser New York of our Navy. Her dimensions are, *length* 380 feet, *beam* 65 feet, *draft* 26⅔ feet, *displacement* 8,200 tons. Her protection against direct fire is made up of an armor belt, armored turrets, and shields. The *armor belt* is 4 inches thick and extends the entire length of the ship. The *protective deck* extends from bow to stern; it is horizontal along the axis of the ship and inclined along the sides. The horizontal part is 3 inches, and the inclined part is 6 inches thick. The *barbette* of the turret emplacements for the 8 inch guns is 10 inches, and the *revolving* turret 7 inches thick. The *shields* which inclose the sponsons for the small guns are 4 inches thick. The protection against high angle fire is the protective deck, and against submarine attack, the cellular bottom and water tight compartments of the hull. The armor of an armored cruiser is intended to afford protection against the direct impact of the armor-piercing, rapid fire guns.

The heavy armament is made up of six 8 inch guns, two in each turret, and two mounted in broadside; and twelve 4 inch rapid fire guns in sponsons along the sides; the light armament consists of eight 6 pound, and two 1 pound, rapid fire guns, and two machine guns. Armored cruisers could not alone attack sea-coast defenses, but as they make a part of every naval fleet, they must be considered in discussing the probable naval attack. In the

principal foreign ships under construction the heavy armament consists of two 9.2 inch, and twelve to sixteen 6 inch rapid fire guns; the light armament consists of seventeen smaller guns.

Coast Defense Vessels.—Coast defense vessels are heavily armored vessels with a low free-board, which are not intended to operate on the high seas. They are intended primarily to break blockades, to protect defenseless harbors, and to assist the fixed defenses in protecting fortified ports. If, however, the navy of the enemy has been rendered powerless to threaten a counter attack, they may be sent to assist battleships in an attack upon a foreign port. Pl. XVII, Fig. 2 shows the characteristics of this type of vessels, being a diagram of the coast defense vessel Monterey of our Navy. The dimensions of this vessel are, *length* 256 feet, *beam* 59 feet, *draft* 15⅓ feet, and *displacement* about 4,000 tons. Her protection against direct fire consists in an *armor belt* of 13½ inches of steel, *two turrets*, one of 14, and the other of 11½ inch armor, an *armored conning tower*, and a *protective deck* 3 inches thick.

The heavy armament consists of two 12 inch, and two 10 inch guns, in turrets; the light armament of six 6 pound and four 1 pound rapid fire guns, and two machine guns.

Unarmored Vessels.—The unarmored vessels of a navy are unarmored cruisers and torpedo boats. The only protection of the former lies in a protective deck and light armor about the guns. The armament is similar to, but less powerful than that of the armored cruisers. Torpedo boats and torpedo boat destroyers are very fast unarmored boats, which attend a fleet to protect it against attacks of similar hostile boats. To be sea-going, they must be at least 125 feet long, and have a draft of 7 feet. The armament consists of small rapid fire and machine guns, and spar and automobile torpedoes. In the attack of a fortified port, they would protect the fleet from counter attack, and assist in the removal of submarine mines.

Methods of Attack.—The object sought by a naval

attack against land defenses may be first, by simple bombardment to injure the armament and shelters of the defense, and to demoralize the garrison so that it will surrender the works; second, to silence the armament and to destroy the shelters so that the works may be taken by assault by a landing party usually disembarked under the protection of the fleet; third, to silence the guns and to demoralize the defenders so that obstructions may be removed and the fleet allowed to steam past the works to reach an objective in their rear.

Attacks by simple bombardment have been very common and occasionally successful. In our Civil War, Fort Henry on the Tennessee river, Forts Clarke and Hatteras at Hatteras Inlet, Forts Beauregard and Walker at Port Royal were either surrendered or abandoned, as a result of a bombardment, before a land attack was made. In 1882, the defenses of Alexandria, Egypt, were also abandoned as a result of a bombardment. Attack by bombardment will not ordinarily result in the capture of coast defenses, if they are properly located and constructed; the bombardment must be supplemented by a land attack. In the examples given above, except Alexandria, the commander of each fort was aware that a land force much superior to his garrison accompanied the attacking fleet; this fact largely influenced him in surrendering or abandoning his works, before they were assaulted.

The second method is the only effective way in which good land defenses can be attacked. The land attack may be a simple assault, or it may be a regular siege, depending upon the strength of the defenses on the land side. In our Civil War, Fort Fisher at the mouth of the Cape Fear river was taken by assault, while Fort Wagner at the entrance of Charleston harbor, Fort Pulaski at the entrance of the Savannah river, the defenses of Mobile, Port Hudson, and Vicksburg were taken by regular siege, usually after one or more assaults had been repulsed. Santiago, Cuba, was also taken, in the Spanish-American War, by a land force, disembarked under the protection of the fleet.

The third method is employed in attacking cities which are situated on the banks of rivers or deep estuaries, where the works of defense are constructed well in advance of the places to be protected. The success of the attack will depend largely upon the character of the obstructions. Guns alone cannot prevent the passage of a hostile fleet, as was shown by the operations of the Union fleet on the Mississippi river during the Civil War, when wooden ships successfully passed Forts St. Philip and Jackson near the mouth of that river, in advancing to attack New Orleans. A channel which is well obstructed by submarine mines in good condition, or other effective means, can only be used by a hostile fleet after the obstructions are wholly or partially removed. The removal of the obstructions is an exceedingly difficult operation and usually involves the capture of the flanking batteries or works.

CHAPTER VII.

ELEMENTS OF COAST DEFENSE.

The various elements which make up the defense of important seaports are guns, mortars, torpedoes, submarine mines, obstructions, harbor defense vessels, torpedo boats, and search lights.

Guns.—Guns are employed to penetrate the sides, and occasionally the decks of naval vessels, and to combat their artillery. They are mounted either in fixed batteries or in harbor defense vessels. They are divided into three classes: heavy armor-piercing guns to penetrate the belt line, bulkhead, barbette, turret, and conning tower armor; light armor-piercing rapid fire guns to penetrate the citadel armor, and armored gun shields; small rapid fire and machine guns to penetrate all unarmored parts of a vessel, to repel boat attacks, and to protect lines of submarine mines and obstructions.

In our service the armor-piercing guns range from the 8 inch to the 16 inch rifle. Their characteristics are given in the following table:

Caliber.	Charge in lbs. Smokeless Powder.	Wt. Projectile in lbs.	Muz. Vel. ft. sec.	Muz. Energy ft. tons.
8 inch	75	300	2250	1052
10 inch	150	575	2300	21090
12 inch	260	1000	2300	36675
16 inch	540	2000	2300	73350

The projectiles for these guns are armor-piercing, common, and torpedo shells.

The light armor-piercing rapid fire guns in our service are the 5 inch and 6 inch rapid fire guns; the smaller rapid

fire guns are the 6 pounder (2.24 inch), and the 15 pounder (3 inch). Their characteristics are given in the following table:

Caliber.	Wt. Charge lbs.	Wt. Projectile lbs.	Shots per Minute.	Muz. Vel. ft. sec.
6 pdr.	1	6	20	1800 to 2500
15 pdr.	3	15	20	1800 to 2500
5 inch.	30	50	10	2300
6 inch.	50	100	7	2150

The penetrations of all armor-piercing guns in wrought iron or soft steel may be roughly determined by using Captain Orde Browne's rule of one caliber penetration for every thousand feet of remaining velocity. More accurate formulae are given in ordnance manuals. The penetration in Harveyized or Krupp steel is very much less.

The machine guns in our service are the Gatling and Gardiner guns.

Mortars.—Curved or high angle fire of howitzers and mortars is employed to attack the decks of naval vessels. In our service the 12 inch mortar is used for this purpose; the characteristics are given in the following table:

Caliber.	Charge lbs.	Wt. Projectile in lbs.	Muz. Vel. ft. sec.	Muz. Energy ft. tons.	Range at which it can penetrate armored decks.
12 inch	105	800–1000	1140	7206	1 to 5 miles.

Torpedoes.—Torpedoes are employed either to attack the hulls or decks of naval vessels, and are of two kinds, aerial and submarine. The former are projected through the air, and the latter are projected or propelled underneath the surface of the water.

Aerial torpedoes, in our service, are projected from pneumatic guns, and are of two calibers, the 8 inch and the 15 inch torpedo. The contract specifications of the 15 inch pneumatic guns mounted in our defenses are:—

To project a shell containing 50 lbs. of explosive 5,000 yds.
" " " " 100 " " 4,500 "
" " " " 200 " " 3,500 "
" " " " 500 " " 2,000 "

At the maximum range one-third of the shots must fall in an area 360 x 90 feet. It is also proposed to use this weapon in attacking the hulls of naval vessels, by exploding the torpedoes under water, in the vicinity of the hull.

Submarine torpedoes are water-tight boats containing a large charge of explosive and some form of motor for propelling them underneath the surface of the water, so that they will strike a naval vessel below the belt armor. They are divided into two classes, the *simple automobile* and the *dirigible torpedoes*. To the first class belong the Whitehead, Schwartzkopf, and Howell; to the latter, the Brennan, Sims-Edison, Lay, and various others. The *Whitehead torpedo* has a cigar shaped body of steel, from 11 to 19 feet long, and from 11 to 19 inches in diameter. Its motive power is compressed air which operates two twin screw propellers, and gives the torpedo a velocity of 28 to 29 knots for a range of 1000 to 1500 yards. The head of the torpedo contains 100 or more pounds of explosive, ignited by a percussion or a delayed action fuse. The submergence and direction of the torpedo are regulated by vertical and horizontal rudders operated by an ingenious and complicated mechanism. The torpedo must be carefully aimed, as it is beyond the control of the operator as soon as set in motion. The *Schwartzkopf* is simply a modification of the Whitehead torpedo, the case being phosphor-bronze. The *Howell torpedo* is similar to the Whitehead in appearance; it contains less mechanism, and can be made smaller, for the same amount of explosive. The motive power is the energy stored in a fly wheel weighing 130 pounds, which is given a speed of 10,000 revolutions a minute by a jet of steam. The rotatory motion of the wheel tends to keep the torpedo in its original path. The charge is 100 or more pounds of explosive, as in the Whitehead. Small changes in submergence and direction are effected by vertical and horizontal rudders operated by special mechanism. These simple automobile torpedoes are intended primarily for use on naval vessels and torpedo boats, where they are aimed by means of launching tubes;

should a fleet be blockaded in a harbor, they might also be used in harbor defense.

Dirigible torpedoes are automobile torpedoes which are under the control of the operator until they have completed their runs. During this time the torpedo may be stopped, or the direction of the path changed; in some torpedoes the change may be as much as 360°. There are many varieties of these torpedoes differing in their motive powers.

The *Brennan torpedo*, adopted by Great Britain, is propelled and directed by means of two strong steel wires which are wound on reels in the torpedo and are rapidly unwound by a stationary engine on shore. These wires unwind at high velocities smaller and finer wires which are wound on spools attached to the two propellor shafts, and thus rotate these shafts. The direction of the torpedo's path is changed by means of vertical rudders operated in an ingenious way by varying the stress on the main shore wires. Submergence is secured by horizontal rudders operated by a special mechanism. The torpedo can be directed in a path making an angle of 40° with its straight-away course. Its charge is 200 pounds of explosive, and its velocity is 20 miles per hour over a range of one mile. The route of the torpedo is indicated by a track of calcium phosphate which burns when it comes in contact with the water.

The *Sims-Edison torpedo* is used in this country, and is propelled by a dynamo on shore, which operates a motor inside the torpedo; the connection between the two is a cable which is stored in the torpedo and is gradually paid out as the torpedo moves. It is directed by means of a vertical rudder operated by an electric current. The torpedo is suspended at a fixed distance below the surface of the water by a float; the float is filled with a light substance which stops the leakage through any holes formed by the assailed vessel's machine or rapid fire guns. Before acceptance by the government, each torpedo is required to develop a speed of 18 miles an hour over a range of one

mile, to steer in an arc whose radius is 300 feet, and to dive at full speed without injury under a floating spar. Its charge is 100 to 200 pounds of explosive.

Other dirigible torpedoes employ compressed carbonic acid gas, storage batteries, ammoniacal gas, or compressed air as their motive powers. The direction is usually given by a vertical rudder which is operated by a current of electricity, carried by insulated wires stored in the torpedo and paid out as in the Sims-Edison.

Submarine torpedoes are valuable in harbor defense, as they may be used in harbors in which the channels are too deep, the currents are too swift, or the tidal range is too great for the use of submarine mines.

Submarine Mines —A submarine mine is a case containing a sufficient charge of explosive to destroy the hull of a vessel, and some form of detonator for exploding the charge. Since the effect of the charge varies with its explosive force, its amount, and inversely as the square of the distance, it is essential to use a high power explosive, a large charge, and to explode the mine as close as possible to the hull of the vessel.

The available explosives in the order of their approximate strength are as follows:—

Explosive Gelatine,	100	relative	strength.
Dynamite No. 1,	80	"	"
Guncotton,	80	"	"
Fine Gunpowder,	30	"	"

Submarine mines are classed as buoyant and ground. A *buoyant mine* is one which floats underneath the surface of the water, between the level of the armor belt and the keel of the naval vessel to be destroyed. It is held in place by an anchor so that the explosion may take place in contact with the ship's hull. The case must be strong enough to stand the shocks of friendly vessels and have sufficient buoyancy to support its charge, the anchoring, and electric cables. The latter condition limits its use to water not over one hundred feet deep. The mine must not be greatly depressed by the action of the current; this condition limits

its use to channels whose current does not exceed seven feet per second. To offer as little resistance as possible, the form of the mine case is a sphere, cylinder, or frustrum of a cone. The charge is usually 100 to 500 pounds of explosive. The bouyant mine is not suited to channels with great tidal ranges, as it is either exposed at low water, or is below the level of the vessel's hull at high water. Pl. XVIII, Fig. 1, is a section showing the ordinary form of buoyant mine. A is the steel case in which is placed the explosive charge, B. At the bottom of the case is fastened the cylindrical metal cylinder C, in which are placed the circuit closer, the electric fuse, and a small detonating charge of the explosive. D is the insulated conductor wire for detonating the fuse, E is the anchoring cable or chain, and F is the anchor.

A *ground mine* is one which is placed upon the bottom of the channel. In this form of mine there is no limit to the amount of charge, but as the effect rapidly diminishes with its distance from the hull of a vessel, ground mines are not effective in depths of over forty feet. The ground mine may be made in any convenient form, and of steel, wrought, or cast-iron. The mine itself contains the metallic case for the fuse, but the circuit closer is placed in a buoy which is anchored to the mine. This buoy is smaller than the buoyant mine case, but is similar to it in form and construction.

Mines may be electric, mechanical, or chemical, depending upon the character of the detonator. In an *electric mine* the detonator is ignited by a current of electricity; in a *mechanical mine*, by some mechanical device, as a firing pin operated by a spring; in a *chemical mine*, by the chemical combination of two substances which are brought together, as the rupture of a tube of sulphuric acid in a jar of powdered sugar. The electric mines may be judgment, contact, regulated, or self-acting mines. In a *judgment mine*, one conducting wire of the fuse is attached to the mine case, and the other is connected through a *circuit closing key* to one pole of a powerful storage or other

form of battery, the other pole being connected with the earth. By simply closing the key, the operator can detonate the fuse and explode the mine. This arrangement is shown in Pl. XVIII, Fig. 2, in which E represents an earth plate at one end of the circuit, and the mine case at the other. F B is the firing battery, K is the circuit closing key, and F the fuse in the submarine mine. In order that the mine be effective, the operator must close the key at the exact instant in which the vessel is in the destructive radius of the mine. This involves an exact knowledge of the location of the mine, which may be swinging about its anchorage due to the force of a variable tidal current, and an exact knowledge of the location of the vessel at each instant. It is rarely possible for the operator to locate both mine and vessel so accurately that the simple judgment mine will be effective. Judgment mines are of no value in a fog, or in a heavy rain storm.

The *contact mine* is arranged in the same manner as the judgment mine except that an automatic circuit closer is placed either in the buoyant mine, or in a buoy floating over the ground mine. It is closed by the shock of the striking vessel. To insure the explosion of the mine at the proper instant, the operator keeps the shore key closed. When the enemy is not in the vicinity he may render the mine inoperative, by keeping the shore key open. This arrangement is shown in Pl. XVIII, Fig. 3, in which the circuit closer is represented as a hammer, formed of a thin vertical steel rod with a heavy metallic head, which is inclosed in the metallic cylinder of the submarine mine. The shock of a striking vessel closes the circuit by bringing the head of the hammer into contact with the sides of the case. The simple contact mine cannot be fired by judgment, nor can it be tested for continuity of circuit.

The *regulated mine* is arranged similarly to the contact mine, but is connected with a weak battery and an annunciator board. When the mine is struck, its number is dropped, and the operator is at once informed that a vessel is in the mine field. If it be a hostile vessel he can

switch into the circuit the firing battery which will detonate the fuse and explode the mine; or if he desires, he can arrange the switches so that the firing battery is switched into the circuit automatically, by the dropping of the corresponding number on the annunciator board. The mine is now arranged so that it is always on guard, but is dangerous to the enemy alone. To insure the continuity of the conductor, a fine wire shunt may be made between the conductor and the metallic case, so that a break in the conductor may be at once detected by a galvanometer. This arrangement is shown in Pl. XVIII, Fig. 3 in which SB is the signal battery, AR the annunciator, and R a high resistance coil which completes the circuit of the signal battery. A shunt circuit is also arranged so that the mine may be fired by judgment; this is omitted in the figure.

A *self-acting mine* is a mechanical, chemical, or electric mine, in which the entire detonating apparatus is in the mine. It explodes whenever it is struck by a vessel and is equally dangerous to friend and foe.

If all the mines of an extended field had separate shore conductors, the bottom of the channel would be a net-work of cables which would render the task of repairing any one cable, almost hopeless. The main shore connection for a group is, therefore, a *multiple cable*, or a cable containing a number of separate insulated strands usually seven. The multiple cable runs from the operating room on shore to a grand junction-box, where each strand is joined to a single cable. Each single cable may in turn run to another junction-box, where it is joined to single cables running to several mines. Where several mines are connected with the same conductor, a cut-off is arranged so that the explosion of any mine cuts its connection in the junction-box, and prevents the leakage which would otherwise occur. The entire system of mines attached to the same multiple cable is called a *grand group*; the system attached to the separate strands of a multiple cable is called a *minor group*. The different mines of a group are separated from each other by such a distance, that the explosion of any one

mine will not injure the case, anchorage, or the electrical connections of its neighbors; for mines containing one hundred pounds of explosive, this is about 100 feet. The arrangement of a grand group of mines is shown in Pl. XVIII, Fig. 4, in which A is the multiple cable, B the grand junction-box, CC the minor junction-boxes, and MM the separate mines, When a number of contact mines are strung along a single conductor cable, each is called a *skirmish mine.*

The *operating room* on shore, which contains the firing battery, the signal battery, the annunciators and switches, is placed in an unexposed position, and is made proof against naval fire. It is connected with the channel by a tunnel in which are laid the multiple cables.

The weakness of any mine system lies in the injuries caused by passing friendly vessels, and the leakage from defective insulation; these may render the mines inoperative at the critical moment.

Submarine mine fields must be swept by the fire of rapid fire and machine guns which will prevent the removal of the mines by the enemy. In the attack of a mine field, a fleet may resort to countermining, sweeping, or creeping. *Countermining* consists in exploding, along the channel which is to be opened, large charges of explosive to break the mines, insulated cables or anchorages. These charges may be in the form of aerial torpedoes; or submarine mines, placed and exploded by the launches and torpedo boats of the fleet. *Sweeping* consists in dragging over the mine field a long cable attached to two boats. When an anchor cable is encountered, it is destroyed by a small charge of explosive; the mine floats to the surface and its shore connection is severed. *Creeping* consists in dragging hooks along the bottom near the shore, so as to find and destroy the main electric cables connecting the torpedo system with the operating room. At night and in a fog, patrol boats must be employed to give warning of the approach of an enemy's boat parties. The mine circuits *may be also* connected with the flanking guns so that it

any mine is interfered with, its vicinity will be swept by the fire of the guns.

Obstructions.—Obstructions are any passive obstacles which prevent a hostile fleet from using a channel, until they are removed. Like submarine mines they must be under the guns of the batteries. They may be either floating or fixed. Floating obstructions are chains and cables supported by booms, rafts, etc., which extend from shore to shore; they are used in closing narrow channels. They are objectionable, as they are liable to be carried off in floods, and they limit the movements of friendly naval and merchant vessels. The floating obstruction, which was constructed by the Confederates across the Mississippi below New Orleans, parted, during a flood, just before the arrival of the Union fleet under Admiral Farragut. Fixed obstructions are cribs, piles, sunken barges, submerged dikes, etc., which wholly, or partially, close a channel. They were extensively used in our Civil War as they are very difficult to remove. When an active defense is to be made, gaps must be left for the passage of friendly vessels; these may be in water too shoal for the passage of war vessels, or they may be under a heavy concentrated fire of the shore batteries. The entrance to Spezia harbor in Italy, is partially closed, in a permanent manner, by a submerged dike; the gaps are near the shore and under the close fire of heavy turret guns.

Harbor defense vessels are similar to coast defense vessels, but still further sacrifice speed and seaworthiness to secure a heavy armament, well protected by armor. They are employed in harbors, where land batteries combined with submarine mines cannot effectually close the entrance. A harbor with a very wide entrance, or with a very deep channel, would require harbor defense vessels to replace coast batteries or submarine mines.

Torpedo boats armed with simple automobile or spar torpedoes assist the coast defense vessels. A *spar torpedo* is a large torpedo shell, attached to a spar, which projects from the bow of a launch or tug, and is so arranged that

it explodes on contact with an obstacle. The spar is so fixed that the torpedo is exploded in contact with the hull of a battleship, below the belt armor.

Search lights enable the defenders to watch the movements of the fleet at night, and detect any attempts to destroy the submarine mines, or to land parties for an assault. These lights may be placed in disappearing turrets, as in land defenses, or on disappearing mountings behind a parapet. The lights may also be placed on carriages so as to be moved from point to point.

CHAPTER VIII.

TURRETS, CASEMATES, AND BARBETTE BATTERIES.

The *heavy armor-piercing* guns of coast batteries are mounted in turrets, casemates, or in barbette batteries.

Turrets.—The turret mounting has the advantage of all-round fire, and all-round protection for the gun and its detachment; the chase of the gun alone is exposed to fire. The principal objection to it is its cost, which limits its use to low contracted sites where practically all-round fire and protection are deemed essential; an additional objection is its contracted interior space. There are two general types of turrets, the cylindrical and the spherical; the former may be made of wrought iron, compound amor, or steel; the latter is made of chilled cast iron. *Wrought iron turrets* are employed in the defenses of Dover in England, St. Petersburg in Russia, Antwerp in Belgium, and Callao in Peru. The Dover turret, which may be taken as a type, is a cylinder whose interior diameter is 32 feet and interior height 9 feet. The sides are made of three layers of 7 inch wrought iron plates, separated by two layers of 2 inch plates. The total thickness is, therefore, 25 inches. The total weight of the turret with its two 16 inch, 80 ton, muzzle-loading, rifles is about 1,000 tons, which is borne by a ring of steel rollers. The turret and guns are operated by a 200 horse-power steam engine. The loading rooms, magazines, etc., are in the pier upon which the turret is constructed. Cylindrical turrets would now be made of steel, which has replaced wrought iron in armor construction. The requisite thickness would be determined by the table of penetrations of the most powerful gun afloat.

The *chilled cast-iron turrets* are made by the Gruson Company of Germany. They are of the well-known mushroom form, and are made of large blocks of metal which support each other as the voussoirs of a dome. This obviates the necessity of using bolts which are elements of weakness in cylindrical turrets; the voussoirs are held in place by steel keys which are inserted in grooves in their sides. The use of steam power is avoided as far as possible, and in those recently designed for guns all 11 inch caliber or less, the turrets and guns are maneuvred entirely by man-power, or by means of hydraulic accumulators filled by hand pumps. A turret for two 11 inch guns requires a detachment consisting of one officer, and forty-one men. This turret is 34½ feet exterior diameter, and with its substructure of iron plates and angles, is nearly 20 feet high. Like the smaller turrets for land defense, the weight of the turret is borne by a ring of conical steel rollers. The weight resting on these rollers is 827 long tons; in addition to this the glacis armor weighs 460 tons. The resisting power of the turret is estimated as 22,600 foot-tons, or about the striking energy of a 12 inch gun fired at a range of 2,200 yards. These turrets are used in the coast defenses of Europe, on the coasts of Germany, Holland, Austria, and Italy, and in the defenses of Rio Janeiro, Brazil.

Casemates.—If the front of attack be limited, the casemate mounting has the advantage over the barbette mounting of thoroughly protecting the guns and detachments from the enemy's fire and of allowing the guns to be spaced with intervals of 30 feet; it has the advantage over the turret, of giving more interior space. It has the defects of a narrow field of view and fire, usually limited to a sector of 70 degrees; and, if of armor, of costing nearly as much per gun as a two gun turret. These defects tend to limit its use to low, contracted sites, which command narrow channels. In Great Britain and the United States, the casemate has been wholly replaced in the new coast defense plans, by barbette mountings.

Before the invention of rifled artillery, the typical

battleship was a wooden vessel carrying from 70 to 120 guns, which were mounted in broadside in two or more tiers. At this time the typical land battery was a circular, or polygonal, masonry structure, usually constructed on a low site near the channel; it had several tiers of guns in casemates, and was surmounted by a tier of guns in barbette. In the earlier works, the masonry was brickwork, but in the later works dimension granite was substituted for the brick, and the walls were made eight or more feet thick. Examples of both types may be seen in New York Harbor; Castle William on Governor's Island belonging to the former, and Fort Wadsworth on Staten Island to the latter. The first attacks made on works of this class with large rifled guns, were the siege of Fort Pulaski, Ga., on the Savannah river, and the bombardment of Fort Sumter, Charleston, S. C., conducted by General Gillmore of the Corps of Engineers, during our Civil War. In these attacks it was shown that masonry works of the old type were no longer able to withstand the fire of the new rifled guns.

At this time Great Britain was undertaking the construction of an extensive system of coast defenses which were begun in 1860, and were to cost about $50,000,000. Since they were begun in accordance with the prevailing type of sea-coast batteries, in the course of construction it became necessary to modify that type so as to meet the new conditions. After an exhaustive system of experiments, it was decided to strengthen the new works with *iron shields*. In the less exposed sites, the shields, either flat or curved, were used to close the fronts of the casemates only, and were separated by massive piers of masonry 14½ feet thick. In the more exposed sites, the shields formed a continuous wall of iron in front of the casemates. The shields were pierced by gun-ports which were 4 feet high and 2½ feet wide. The typical form of shield adopted in 1870, was the *sandwich shield*, consisting of three wrought iron plates each 5 inches thick, separated by two layers of concrete, *made of tar and* iron turnings, each 5 inches thick. The

plates were connected by bolts, which fastened the intermediate plate to each of the others. The shields used in closing the casemates were made of single plates each 8 x 12 feet; the continuous scarps were made in the same manner of smaller plates or *planks*. Some of the barbette batteries were also converted into casemates, by erecting a shield between two traverses, and covering the emplacements with a temporary, or permanent, splinter-proof roof.

In 1870 the Gruson Company began the construction of casemates composed wholly of chilled cast-iron. This casemate, as at present constructed, is shown in Pl. XIX, Figs. 1 and 2. Fig. 1 is a vertical section and elevation of the casemate through the embrasure; Fig. 2 is a horizontal section and plan of the chilled iron face, also through the embrasure. Some of the advantages over other types claimed for the chilled iron casemate are, the surfaces exposed to fire are double curved surfaces; no bolts are necessary in its construction; and the shock is transmitted to a large area of structure by the voussoir construction. These casemates are found in the coast defenses of Germany, Austria, Holland, Belgium, and Italy. At the mouth of the Weser, is an armored casemate for nine guns, surmounted by three two-gun turrets. In France some of the old masonry works have been strengthened by increasing the thickness of the scarp walls by an exterior wall of concrete, 25 or more feet thick. This makes the gun-ports very large and deep, which is objectionable.

Barbette Batteries.—The barbette mounting being the most economical, is the one generally adopted for sea-coast guns. If the gun be mounted on a center pintle carriage it may have an all-round fire like the turret; if on a front pintle carriage, the flank guns of a battery sweep over a sector of 170 degrees, and the interior guns over a sector of 140 degrees. If the site be an elevated one, the simple barbette mounting gives the gun all necessary protection against naval fire; and if the site be low, the disappearing mounting gives the additional protection *required.* The gun detachments may be almost as safely

screened from shell fragments and shrapnel as those in turrets and casemates, by the use of vertical or horizontal shields attached to the gun carriages. An objection to the barbette mounting is the great horizontal development of the battery, which prevents its use in very contracted sites.

The simple barbette mounting is the most economical, and in our defenses costs, including emplacement, gun, and carriage, about $50,000 for the 8 inch gun, $60,000 for the 10 inch gun, and $100,000 for the 12 inch gun. A vertical shield may be added for the protection of the gun detachment while loading and pointing the gun. In elevated sites the simple barbette offers a difficult target to naval fire. At Santiago, Cuba, the Morro and Sacopa batteries were on opposite sides of the entrance, on bluffs 200 feet high; on June 6th, 1898, these batteries were attacked by twelve naval vessels and auxiliary cruisers, mounting 112 guns of 4 inch caliber or above, and a large number of smaller rapid fire guns. Although the bombardment was kept up for three hours, not a single gun of the 12 mounted in the defenses was injured; as the batteries were not provided with bomb-proofs 3 men were killed and 51 wounded. Most of the shore guns being old muzzle-loaders, were unable to do any execution at the range of the ships and soon ceased firing; the fire of the attack was, therefore, delivered under the most favorable conditions.

In low sites, though the guns are not easily hit, the fire of the simple barbette battery can ordinarily be silenced, if the fleet has a much stronger armament. This was well illustrated in the attack on Forts Walker and Beauregard at Port Royal in our Civil War, where the gunners were compelled to abandon their guns under a heavy fire from a fleet of wooden vessels; and in the attacks on the inner lines of Alexandria, where the guns were not injured but the gunners were compelled to abandon them. In low sites, therefore, the guns should be mounted on disappearing mountings.

Disappearing Mountings.—There are two general types of disappearing mountings, the object of each being to

lower the gun during the process of loading so that it will not be exposed to fire. In our service the gun, in its loading position, lies below the trajectory of a shot grazing the interior crest with a fall of $\frac{1}{8}$. This is about the angle of fall of a 12 inch projectile fired at a range of 4,500 yards. One type is the *gun-lift*, in which the gun is placed on a platform which is raised and lowered by powerful machinery. Only a few guns are thus mounted as the cost of the gun-lift has been found to be very great. The other type is the *disappearing gun-carriage*, with or without counterweights; in this the gun alone is lowered, by rotating the axis of the trunnions about an axis below the level of the parapet. In the hydro-pneumatic carriage, used in the British service, there is a horizontal steel shield just below the level of the parapet for the protection of the gun detachment from fragments of shell and shrapnel. The gun is elevated through a slot in the shield, which is also closed by an iron door if the gun is exposed to all round fire; in this type hydraulic machinery is necessary for maneuvering the gun. In our service all guns are maneuvred by man-power, and the horizontal shield is omitted. As compared with the simple barbette carriages the disappearing mountings are more expensive and more complicated; they are thus more liable to get out of order. If steam or similar power is employed to raise the gun, this adds both to the expense and to the complexity of its parts. In our defenses the disappearing mounting costs, including emplacement, gun, and carriage, about $68,000 for the 8 inch; $89,000 for the 10 inch; and $128,000 for the 12 inch gun.

The required thickness of the parapet in front of a barbette is given by most authorities as 40 feet of sand, or its equivalent in concrete; in our service one foot of concrete is considered equal to two of sand. In the concrete are imbedded large irregular stones to deflect the projectiles. This thickness of parapet is based upon the results of the bombardment of Alexandria where a sand parapet 25 feet thick resisted the shots fired from the 16 inch, 80

ton, muzzle-loading gun. In our new works, the parapets for heavy armor-piercing guns consist of a wall of concrete 15 feet thick, in front of which is a parapet of sand 20 feet thick. This is thicker than is necessary to resist simple penetration and would probably afford a serviceable cover were the earth covering largely displaced by torpedo shells. The triangular profile is the best form of parapet for all barbette batteries, as it offers a difficult target to direct fire. The upper part of the parapet, to a point 7 feet beyond the muzzle of the gun, must be a thick bed of concrete to withstand the blast of the gun.

In a barbette battery, guns are usually placed at intervals of 100 to 125 feet; they are separated by traverses which contain the magazines, loading rooms, etc. In the new works, the magazines are protected from direct fire by at least 30 feet of concrete or its equivalent, and from vertical fire, by a concrete roof at least 10 feet thick; the roof is made flat and is supported by I beams. In hastily constructed batteries, the roof may be made of one or more layers of railway rails placed in close contact, and covered with planks or beams to support an earth covering. As the magazines, loading rooms, etc., are usually below, and at some distance from the loading platform, ammunition hoists or lifts, and overhead railways are provided for the movement of ammunition. Pl. XIX, Figs. 3 and 4 show the section and plan of an emplacement for a barbette gun on a disappearing carriage.

In the plan, Fig. 4, the broken line BC is the *interior crest*, and the line DE is the exterior line of the concrete wall which protects the gun emplacement and magazine; the earth parapet is a continuation of this concrete wall. At V is a small recess which is used as an *observation station*. The *terreplein* lies between the interior crest and the broken line FG; it is terminated in rear of the gun emplacement by a parade wall and on either side by rampart slopes which terminate at the parade in the lines HI and KL. The gun-pit at A is sunk below the level of the terreplein, and so constructed as to give the gun a horizontal

sector of fire of 140 degrees. The floors of the magazine M and the other bomb-proof chambers, N, O, P, Q, R, and S are on the level of the parade, so as to allow the necessary thickness of overhead cover. A bomb-proof passage leads from the magazine to the parade, which with iron doors in the parade wall, gives access to the bomb-proofs. A stairway to the left of the gun emplacement and another near the observation station connect the terreplein with the parade.

The *rapid fire* guns may be mounted as in land defenses, in turrets, or in barbette batteries. If in the latter, they are similar to the batteries for heavy armor-piercing guns; the thickness of the parapet, and overhead cover for magazines are however greatly reduced, as these batteries would probably be exposed only to the fire of similar guns afloat. Gun batteries should not be located in front of, or close to, masonry walls or rocky slopes, whose fragments may be thrown into the batteries. A parados in rear of the guns is objectionable, as fragments of shells exploding in its face are thrown back sixty or more yards.

Batteries for *howitzers* and *mortars* are easily protected from direct and shrapnel fire by parapets similar to those for guns, or by placing them in natural depressions. In our service, the mortar batteries are arranged in pits each containing four mortars. The pits are separated by traverses containing the magazines, and may be placed in line, in echelon, or in a square of four pits, depending upon the conformation of the ground. The line and echelon arrangements have the advantage of leaving the pits open to the rear, and thus lessening the chances of injury to the men, by fragments of shells which just graze the parapet.

CHAPTER IX.

ARRANGEMENT OF COAST DEFENSE WORKS.

Caliber of Guns.—The greatest caliber of the guns in the coast defense works of any position depends upon the class of vessels which will probably be engaged in the attack. If the position be of sufficient importance to warrant a serious attack by the enemy's fleet, some of the guns should be equal at least to the heaviest guns afloat, so that no part of any naval vessel would be proof against their fire. The 12 inch gun fulfils this condition. As a certain moral advantage is always secured by having some guns a little more powerful than those of the fleet, heavier guns than any afloat are sometimes mounted in important positions. For the artillery duel, the relative proportion of the heavy armor-piercing, the light armor-piercing, and the smaller rapid fire guns should be approximately the same as on a battleship. All the heavy armor-piercing guns need not be of the maximum caliber, as the heaviest armor is confined to a small portion of a battleship; on the other parts of the ship, the smaller caliber guns are almost equally effective, are less expensive, and can be fired more rapidly. As battleships will not ordinarily operate singly, as long as there is an opposing navy, less important harbors need only be defended by guns of the caliber of the armored cruisers, or unarmored vessels. The largest guns in the first type of vessels are the 10 inch guns, and in the second, the 6 inch rapid fire guns.

Number of Guns.—The number of guns in the coast batteries of any position will depend upon its importance, the hydrography of the field of attack, and the kind of

mounting necessary for each class of guns. The *importance* of the position from a naval, military, commercial, and political point of view, will determine both the nature of the attack, and the amount of money which the civil and military authorities are willing to allot for its protection. The *hydrography of the field of attack* will determine the number of vessels and the guns, which can be utilized by the assailant. If this field of attack be an open one, the water not too deep, nor the current too strong, every vessel may be anchored in line, so as to utilize all the guns of a broadside simultaneously. If the field of fire be narrow and the current swift, the vessels are compelled to advance in column, and if the channel be obstructed, only a few guns of the fleet can be utilized. The *kind of mounting* will determine the number of guns which can be put in position for any given sum of money; this varies from $100,000 for a single 12 inch gun in barbette, to $250,000 for a single 12 inch gun in a two-gun turret. No general rules can be given for the number of guns in coast defense works; the number can only be determined by a study of local conditions.

Line of Defense.—If the object of the batteries be to prevent the destruction of a place by bombardment, the artillery line should, if possible, be located about six miles in front of the position to be protected. This will compel the hostile fleet to silence the batteries, before it can bombard the port which is covered by them. This condition can, however, be fulfilled only in the defense of ports which lie in deep, narrow estuaries, or near the mouths of navigable rivers. When this condition cannot be fulfilled the artillery line should be constructed as far in advance of the position as the topography of the site will permit. Since all the guns of the attack, both heavy and light, are practically in the same line, the same disposition should be made of the counter-battering guns of the line of defense. This will prevent the fleet from concentrating its fire first on the advanced guns of the defense, and then on the retired ones, as might be done if they were established in

separate lines. The principal advantage which the fleet enjoys over land defenses is its mobility; in a favorable field of attack, this permits the fleet to concentrate its fire, and to destroy the land batteries in succession. This advantage can only be neutralized by separating the artillery of the defense into small batteries of from two to four guns, so located that they can bring a concentrated fire upon any vessel in the field of attack. The mortar batteries need not be in the same line with the guns; they are advanced to take advantage of their extreme range of five miles, when the line of defense is near the place to be protected; they may be retired to take advantage of their minimum range of one mile, when the artillery line is six or more miles in advance of the port which is to be protected.

Effect of Elevation.—The effect of elevating a land battery is to increase the angle of fall of the projectiles fired from the land battery, and to increase the angle of elevation and decrease the angle of fall of the projectiles fired from the fleet. It also increases the dead space in front of the battery in which a vessel is safe, but in which it cannot engage the battery.

The increase in the angle of fall, secured by elevating the battery, only becomes of value when it is sufficiently great to enable the shot to penetrate the decks and hull; an angle of fall of 10 degrees is deemed essential for the penetration of the armored deck. The maximum angle of depression of our barbette carriage is 7 degrees; under this angle of depression, a 10 inch gun will strike the deck of a vessel at an angle of fall of 10 degrees, only when the gun is about 1000 feet above the deck, and the vessel is about 2000 yards from the battery. At a less distance, the vessel will be in the dead angle; and between 2000 and 6000 yards, the angle of fall is less than ten degrees. From the above it would appear that the *offensive* power of a gun is not materially increased by a moderate elevation above the sea level.

An increase in the elevation of a battery, increases either *the angle of* elevation at which a vessel's guns must

be fired, or the range from which they must be fired to hit the battery. This will materially decrease the effect of its fire, as was illustrated in the attack of the batteries of Santiago, Cuba; this is the principal advantage of an elevated site. An increase in the elevation of a battery also decreases the angle of fall of the ship's projectiles, and thus increases the protection offered by the parapet. This effect is small, as an increase of elevation of 50 feet for every 1000 yards of range, is necessary to decrease the angle of fall one degree.

The only objection to an elevated site is the dead space which is formed in front of the guns; the width of this space is approximately equal to the elevation of the gun, multiplied by the natural cotangent of the angle of maximum depression of the gun. When the defense of this space is of importance, as in the defense of a narrow channel, the advantages of the elevated site must be sacrificed, or the dead space must be swept by additional batteries.

High-angle Fire. — At the proving grounds of the Krupp works, Germany, in 1890, at the range of 3871 yards, the 29 c. m. howitzer was fired at a horizontal steel deck 17½x4½ yards. The deck was made of three 1 inch plates, and one ½ inch plate riveted together and supported by I beams. With an angle of elevation of 45 degrees, the target was struck by the *tenth* shot, which penetrated the target and the earth beneath. With an elevation of 60 degrees, the target was struck and penetrated by the *sixteenth* shot. At Tokio, Japan, in 1891, a similar target 20x6 yards, and 3 inches thick was hit and penetrated by *three* shots out of *forty-five*, fired at an angle of elevation of 60 degrees, at a range of 3554 yards, from the 28 c. m. howitzer; and by *four* shots out of *seventy-three* from the 24 c. m. mortar. Had the target been of the size of a ship, 20% of the shots would have struck her deck. General Abbot deduces the following formula for the number of shots which would strike a ship, if fired from a mortar battery of sixteen mortars arranged in four symmetrically spaced pits as designed by him; $X=\frac{100}{R^2+1}$, in which X=percentage of hits, and R=the range in yards. The

ship is assumed to lie at the center of impact. From the experiments given and from a study of the construction of naval vessels, it is evident that howitzers and mortars for high angle fire are very valuable elements of any system of coast defenses. In the armament for our coast defenses, recommended by the "Board on Fortifications," the ratio of the number of mortars to that of armor-piercing guns was approximately seven sixths.

High-angle fire is especially valuable to prevent a fleet from lying at anchor to bombard a city, or from taking refuge in an achorage during a storm.

Range and Position Finders.—Range and position finders are provided for each battery to determine the distance and direction of the target from the observing station, and a relocating apparatus is essential for transferring the origin of coördinates from the observation station to the directing gun of each battery, The relocating room is connected electrically with the observation station.

Fire Control.—The united action of the batteries is secured, by connecting the station of the commander of the defenses with that of each battery commander, by means of electric circuits for communicating orders and information; all wires are placed underground.

Defense Against Land Parties.—To defeat an attack by landing parties, auxiliary rapid fire and machine gun batteries are attached to the batteries of large guns; these may be mounted in disappearing turrets or in open batteries. To check an assault, each battery should be inclosed by a strong obstacle, such as a high wire entanglement in a shallow ditch. The flanks of a position should be guarded by strong permanent or field works. A battery in an isolated position, where it can receive little aid from the other land batteries, should be enclosed in a permanent redout or fort of strong profile, with ample bomb-proofs for the garrison and supplies.

Obstructions.—The obstructions are generally placed on the same general line as the batteries, but local conditions may make it advisable to place them in advance,

or in the rear of this line. The submarine mine field is usually of considerable width, and is made up of a number of grand groups of regulated mines, in advance of which are a number of contact, or skirmish mines attached to a single cable. Auxiliary channels may be closed, during the continuance of war, by self-acting mines. The mine field is swept by the fire of machine and rapid fire guns.

Example.—Hampton Roads (Pl. XX), at the mouth of the James River, Virginia, is the best land-locked anchorage on the Atlantic Coast, south of New York, and is the gateway to the navy-yard and coaling port of Norfolk, and to the ship-yards and coaling port at Newport News, Virginia. Unless the entrance to the roads be properly fortified, a hostile fleet may take possession of it to destroy its shipping, the navy-yard, the ship-yards, and the coaling stations which are reached from it, and use this achorage as a temporary base.

The "Board on Fortifications and Other Defenses" recommended for its defense the following:

4 16 inch guns,	2 2-gun turrets,	2 operating rooms,
10 12 inch guns,	10 casemates,	8 electric lights,
20 10 inch guns,	20 disappearing gun carriages,	
16 12 inch mortars,	400 submarine mines.	

The problem of defense which it is proposed to use as an illustration of the principles, is to determine the disposition of these elements to prevent the entrance of the hostile fleet.

Hydrography.—North of the entrance [Pl. XIX] to Hampton Roads is a low peninsula of sand, lying between Chesapeake Bay and Mill Creek; the latter is an extensive shallow tidal basin. The lower end of the peninsula is occupied by Fort Monroe, a pentagonal masonry bastion fort of the old type, which has a tier of casemates and a tier of barbettes, for old muzzle-loading guns. Above Fort Monroe, for a distance of a mile, the peninsula rises only a few feet above the water; beyond that, is a ridge of sand dunes rising to a height of about twenty feet. South of the entrance is another long peninsula, Willoughby *Sandspit*, which is also terminated at the shore end by

a ridge of sand dunes rising to a height of about forty feet. Behind the dunes is low cultivated ground. The main ship channel which enters Chesapeake Bay between Capes Charles and Henry, becomes very much contracted near Thimble Shoal Light; between this light and Hampton Roads its width is only about one mile. Its depth varies between 30 and 85 feet and the tidal current is moderately swift. This channel is limited on the north by Horseshoe Shoal, and on the south by Willoughby Shoal. At the western extremity of the latter is an artificial island made of rip-rap, which is the site of Fort Wool. This is a work of the old type and was originally designed for three tiers of casemates, and a tier of barbettes; only the lower tier of casemates has been completed. An auxiliary channel, 16 feet deep, passes in rear of the fort.

Line of Defense.—Since there is no city to protect from bombardment, the problem is to locate the guns and obstructions so that a fleet cannot steam past the works or successfully attack them. If a line be drawn parallel to the coast and about two miles from it, the deep water area inclosed by the line will be the principal field of attack; beyond this line, the fire of the fleet would be too inaccurate to hope to destroy or to dismount the guns of the defense. The deep water area is that in which the minimum depth is greater than the minimum draft of a battleship; in attacking the batteries at the entrance of Hampton Roads a battleship must keep in the main ship channel. To obtain a concentrated fire upon this field, the line of defense should, if possible, begin at some point north of Fort Monroe, thence extend along the northern peninsula, across the channel at Fort Wool, and along Willoughby Sandspit. The latter, however, is too far from the channel to be a good site for guns, so all the guns must be mounted in Fort Wool, and along the Fort Monroe peninsula. A good site for the two turrets is found either at Old Point Comfort Light, or at Fort Wool. As the greater part of the artillery line is along the peninsula of Fort Monroe, the turrets for the 16 inch guns should be placed in Fort Wool,

and mounted on a line coinciding generally with the axis of Willoughby Shoal. The one to the rear might be elevated above the advanced one, so that it could fire over it. The best position for the casemate, assumed to be an iron one, is near Old Point Comfort Light. Since the guns must sweep a sector of over 100 degrees, extending from Fort Wool to a point beyond Thimble Shoal Light, the casemate for the 12 inch guns should be made slightly curved so that the extreme guns can reach the limits of the zone. The 10 inch guns would be distributed in batteries of from two to four guns, along the Fort Monroe peninsula north of the fort; as the site is low, they should be placed on disappearing carriages. Since the effective range of the 12 inch mortars lies between 1 and 5 miles, the two batteries of eight mortars each would be placed on the flanks of the defense, one at A, and the other at B, where they could reach vessels in and beyond the field of attack. Rapid fire guns, would be distributed along the line to protect the barbette guns from the rapid fire guns of the ships, and to protect the batteries from landing parties. All the batteries in the Fort Monroe peninsula should be protected against night assaults by wire entanglements or other obstructions defended by infantry and machine guns.

The best location of the submarine mine field is between Forts Wool and Monroe, the operating rooms being in these forts. The channel being about a mile wide, it would be entirely closed by two grand groups in line. The regulated mine could be arranged in four lines distant from each other about five hundred feet. This would require 336 mines, the others might be arranged as contact mines in skirmish lines in advance of the main lines, and in the auxiliary channel in rear of Fort Wool. The electric lights would be distributed along the line. In the attack of the defenses at the entrance of Hampton Roads a fleet would be at a great disadvantage in being compelled to attack in a narrow channel. The armament of the defenses could no doubt be safely reduced and it is believed this has been done in the revised projects for this position.

INDEX.

PLATE I

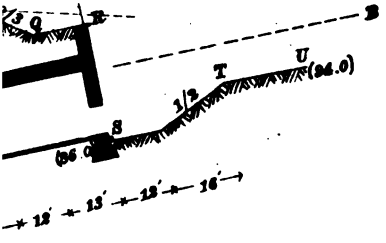
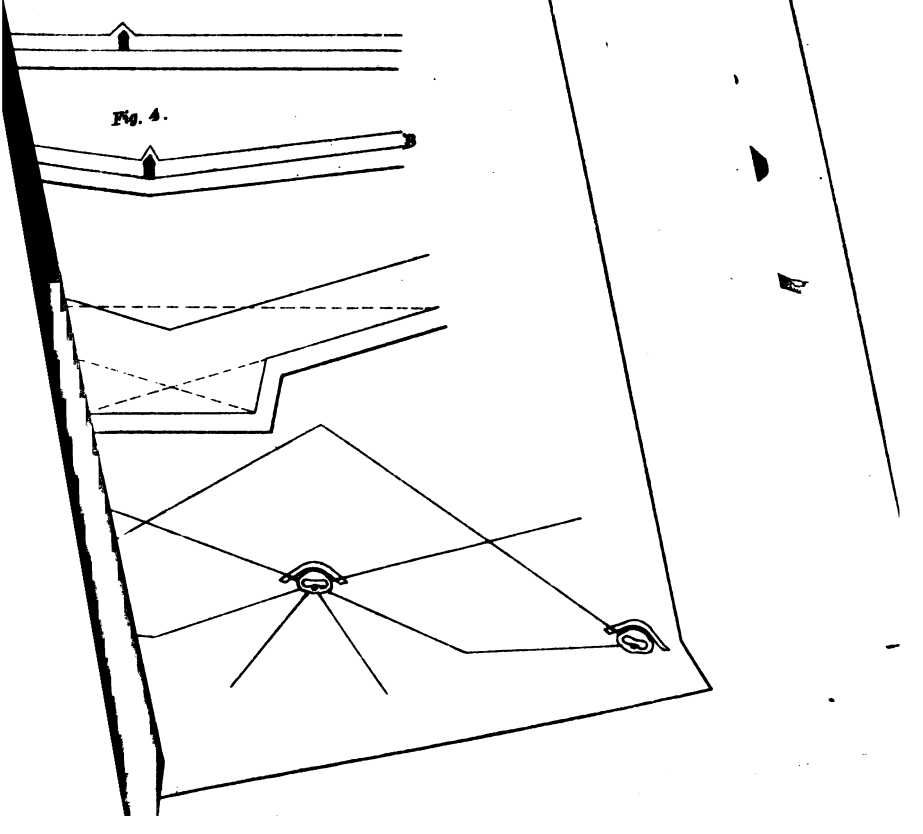


Fig. 4.



TE II

PLATE III

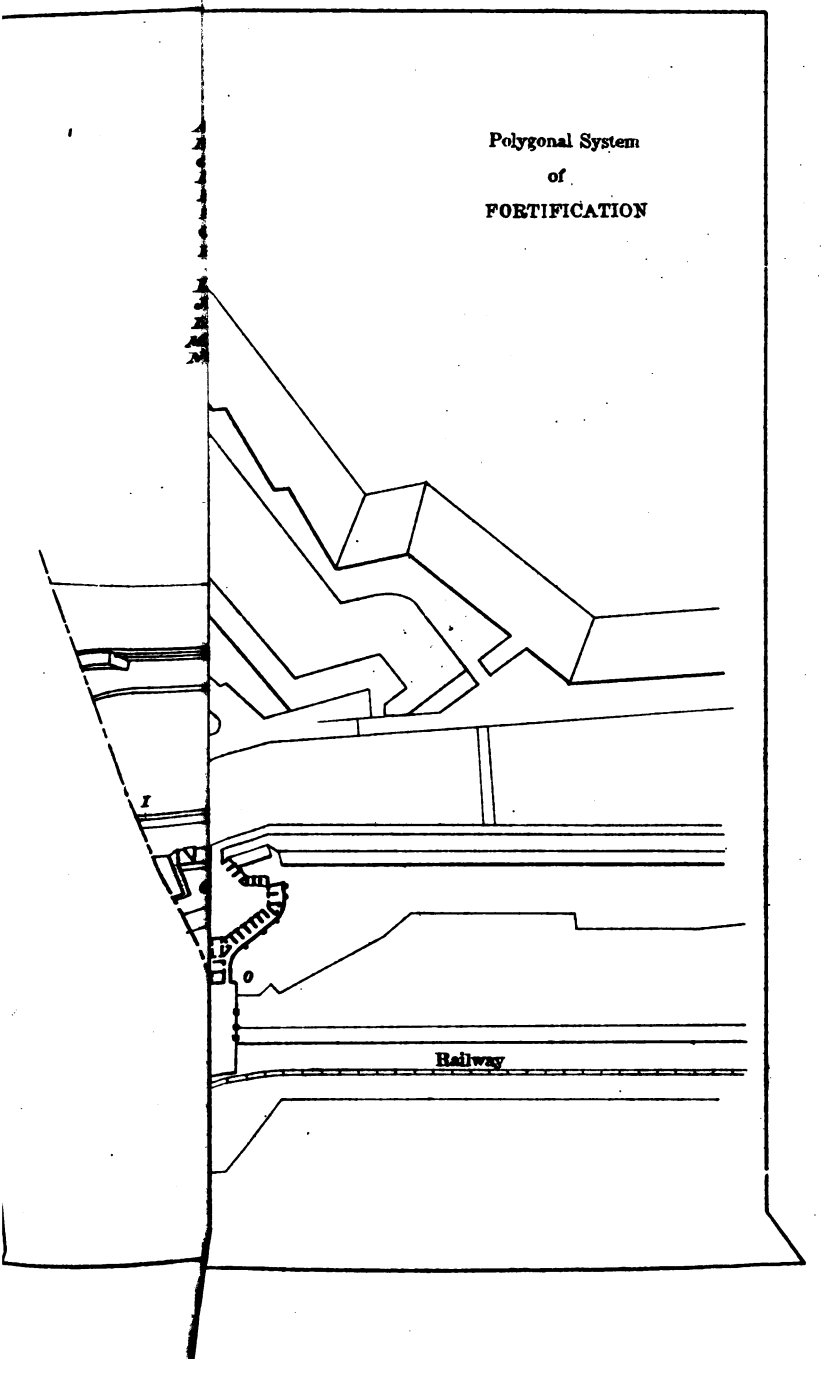


PLATE IV

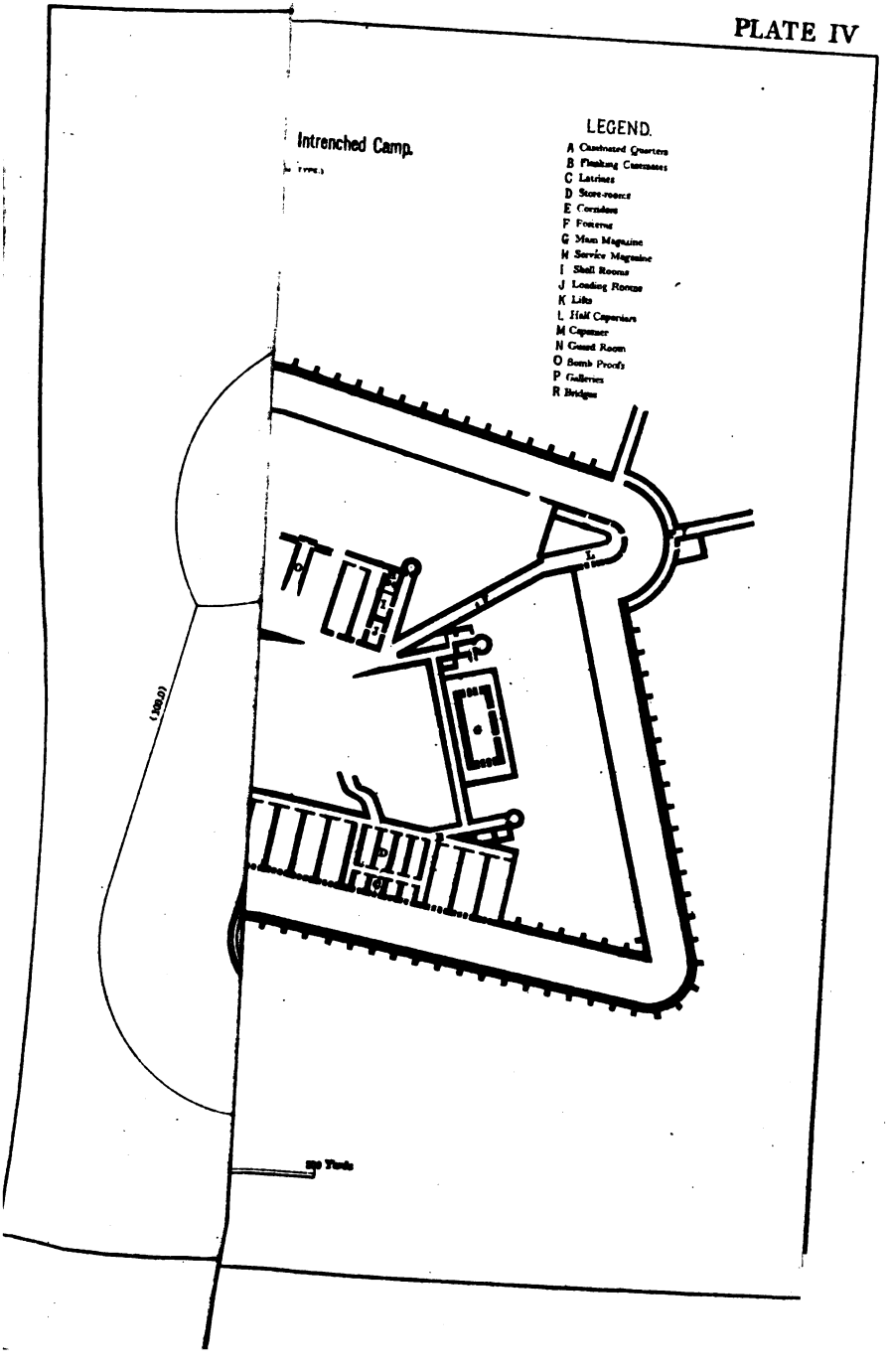

Intrenched Camp.
LEGEND.
A Casemated Quarters
B Flanking Casemates
C Latrines
D Store-rooms
E Corridors
F Traverse
G Main Magazine
H Service Magazine
I Shell Rooms
J Loading Rooms
K Lifts
L Half Caponiers
M Caponier
N Guard Room
O Bomb Proofs
P Galleries
R Bridges
100 Yards

PLATE IV

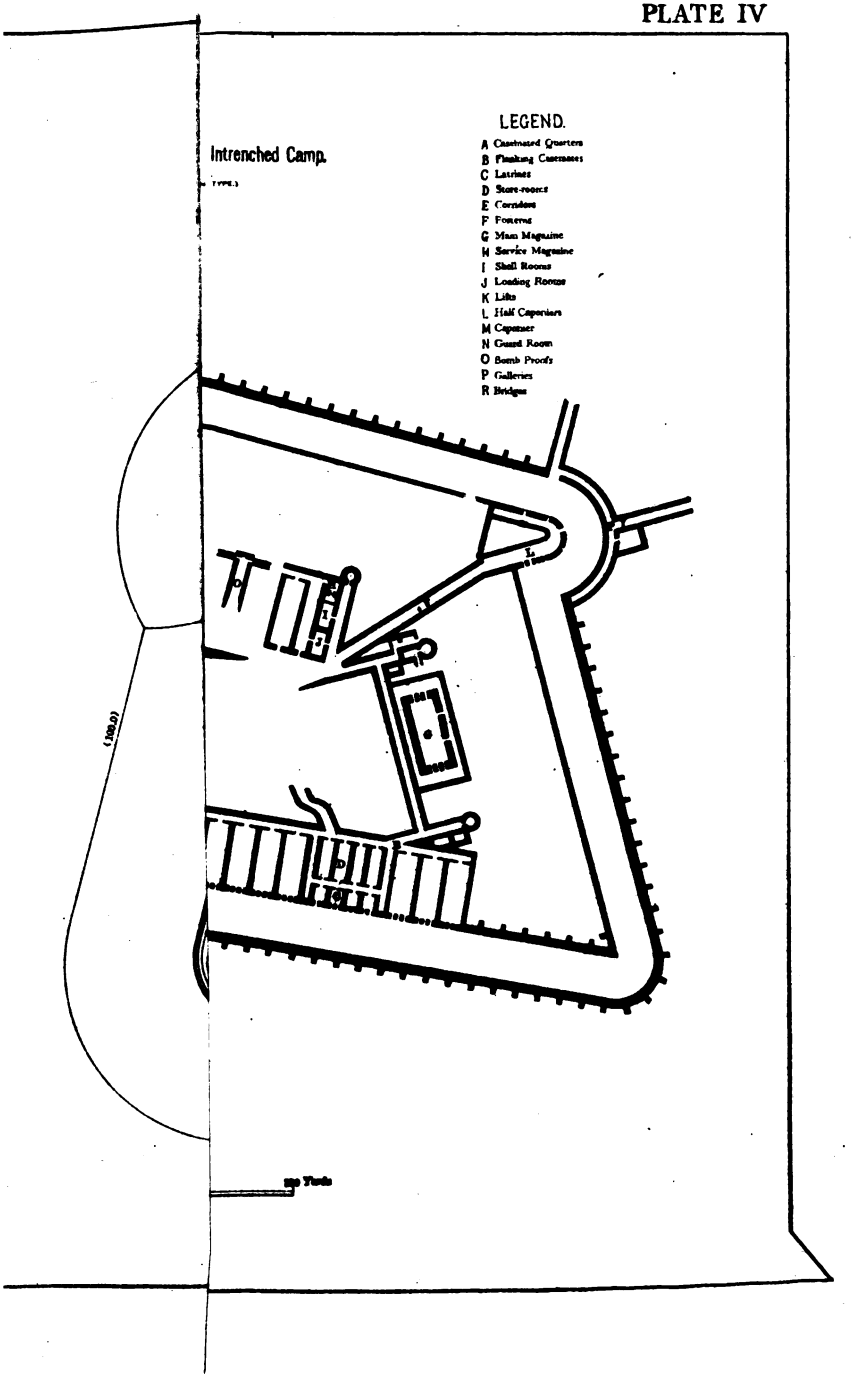

Intrenched Camp.
LEGEND.
A Casemated Quarters
B Flanking Casemates
C Latrines
D Store-rooms
E Corridors
F Fourreau
G Main Magazine
H Service Magazine
I Shell Rooms
J Loading Rooms
K Lifts
L Half Caponiers
M Caponier
N Guard Room
O Bomb Proofs
P Galleries
R Bridges

PLATE V

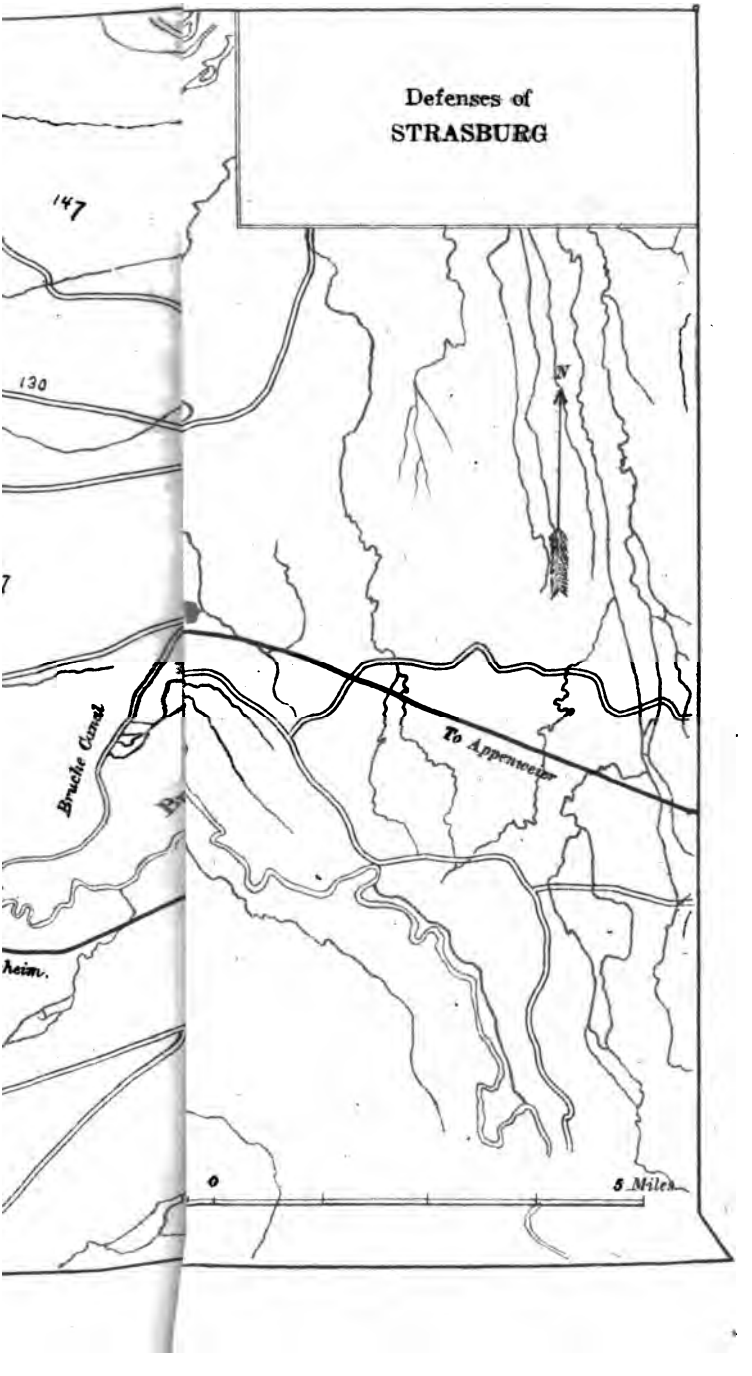
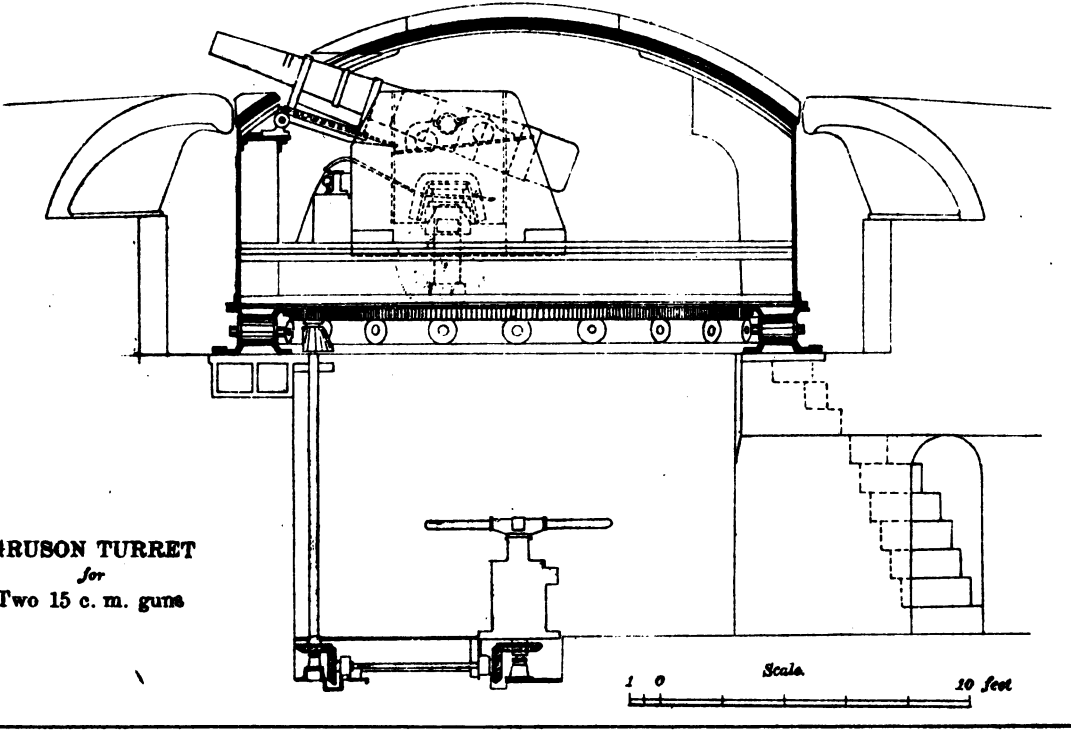

Defenses of
STRASBURG
147
130
N
Bruche Canal
To Appenweier
heim.
0
5 Miles

PLATE IX



GRUSON TURRET
for
Two 15 c. m. guns

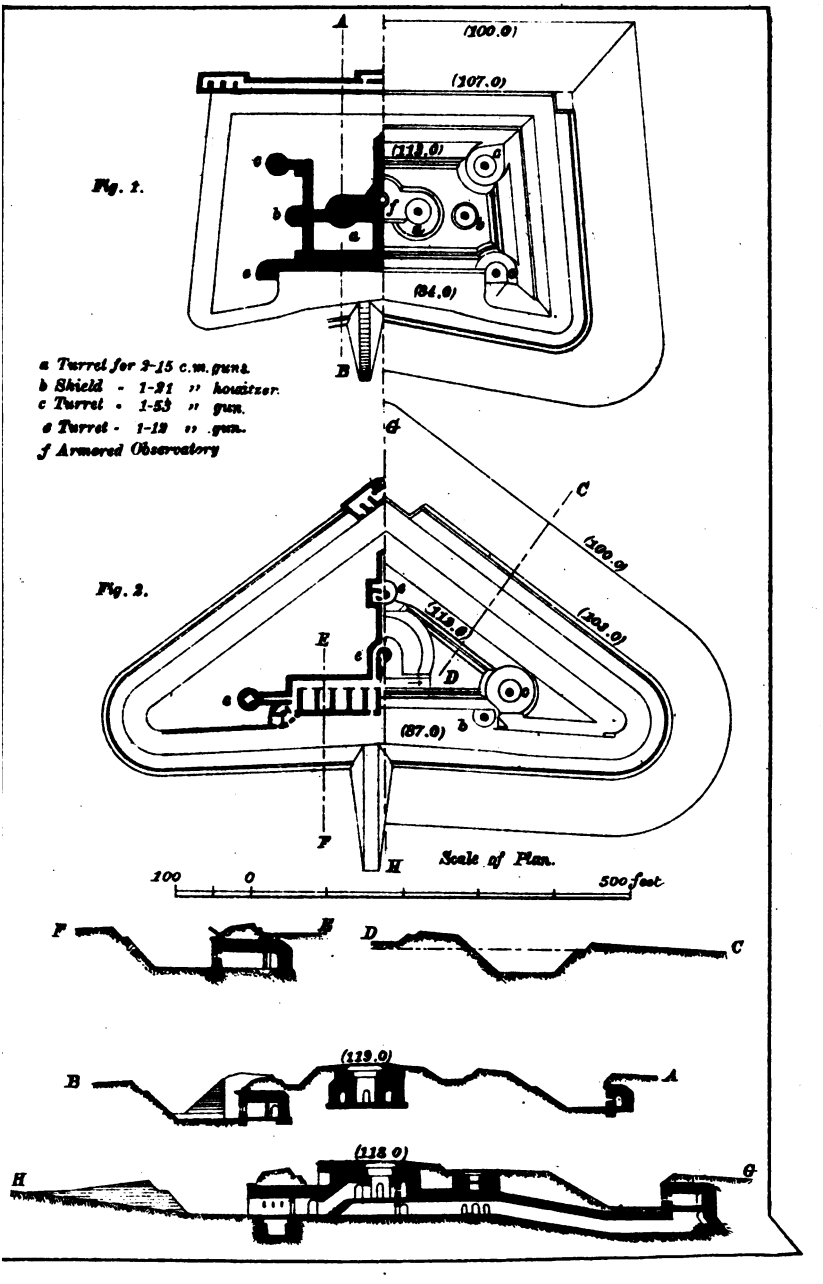


Fig. 1.
a Turret for 2-15 c.m. guns.
b Shield - 1-21 " howitzer.
c Turret - 1-5½ " gun.
e Turret - 1-12 " gun.
f Armored Observatory
(100.0)
(107.0)
(111.0)
(84.0)
B
G
C
(100.0)
(303.0)
Fig. 2.
(115.0)
E
D
(87.0)
F
H
Scale of Plan.
100
0
500 feet
F
D
C
B
(119.0)
A
H
(118.0)
G

PLATE VIII

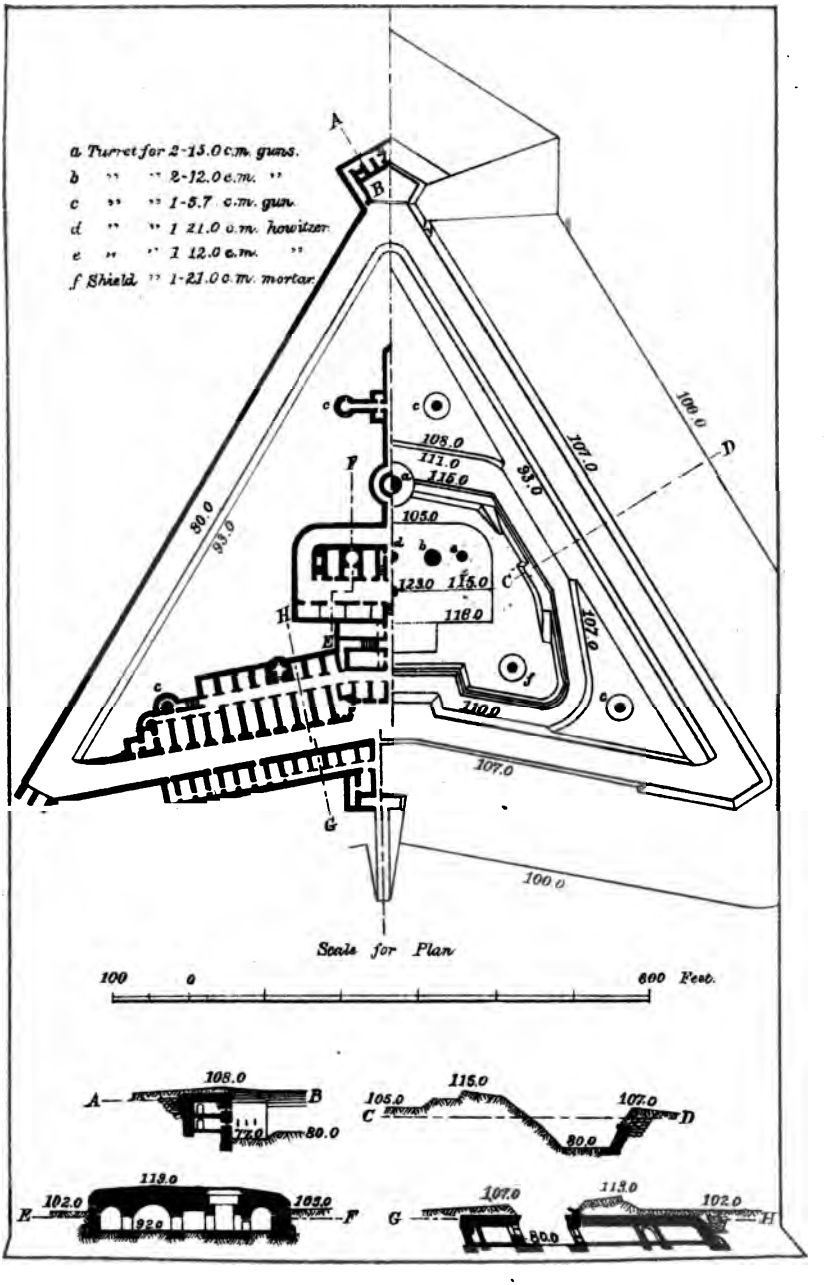

a Turret for 2-15.0 c.m. guns.
b " " 2-12.0 c.m. "
c " " 1-5.7 c.m. gun
d " " 1 21.0 c.m. howitzer
e " " 1 12.0 c.m. "
f Shield " 1-21.0 c.m. mortar
A
B
C
D
E
F
G
H
80.0
93.0
100.0
107.0
93.0
105.0
111.0
116.0
105.0
123.0
115.0
116.0
107.0
110.0
107.0
100.0
Scale for Plan
100 0 600 Feet.
105.0
77.0
80.0
115.0
105.0
107.0
80.0
113.0
102.0
92.0
102.0
107.0
113.0
80.0
102.0

PLATE IX

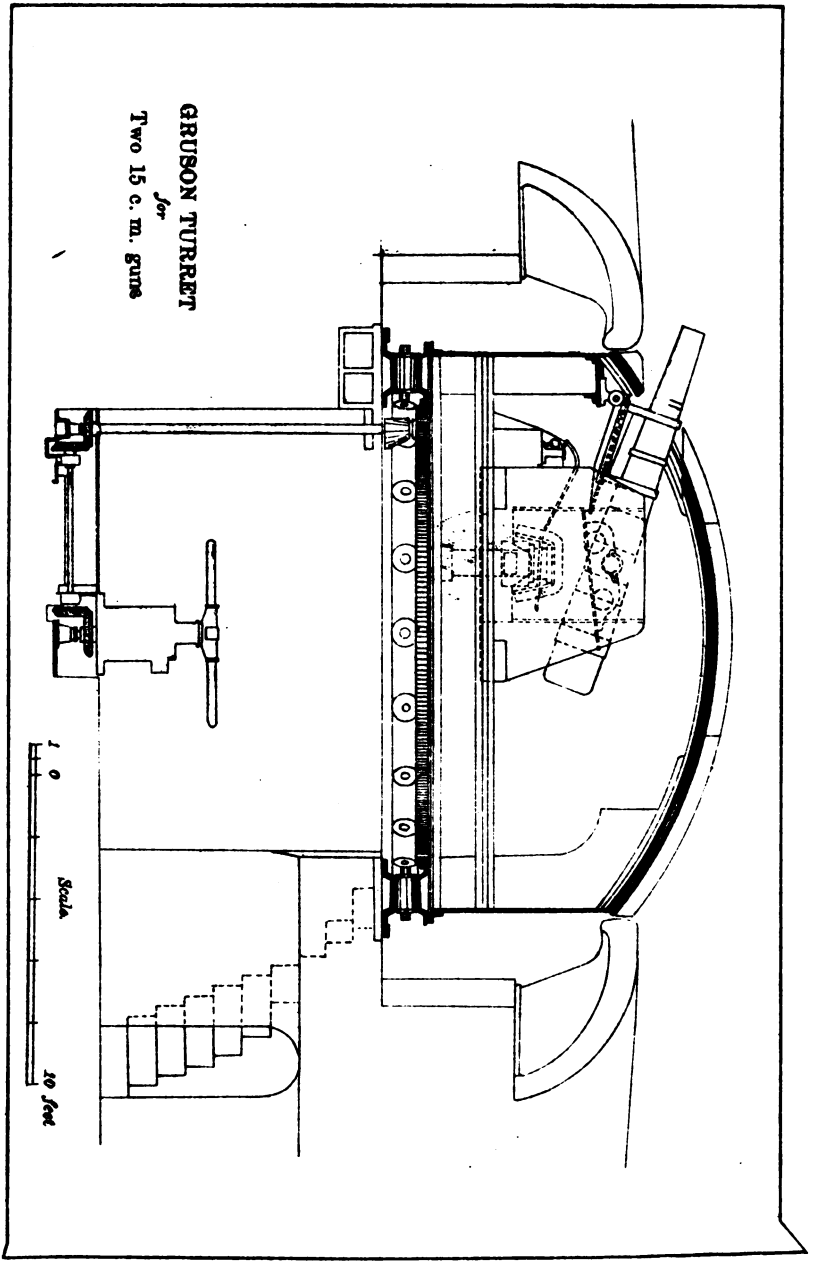
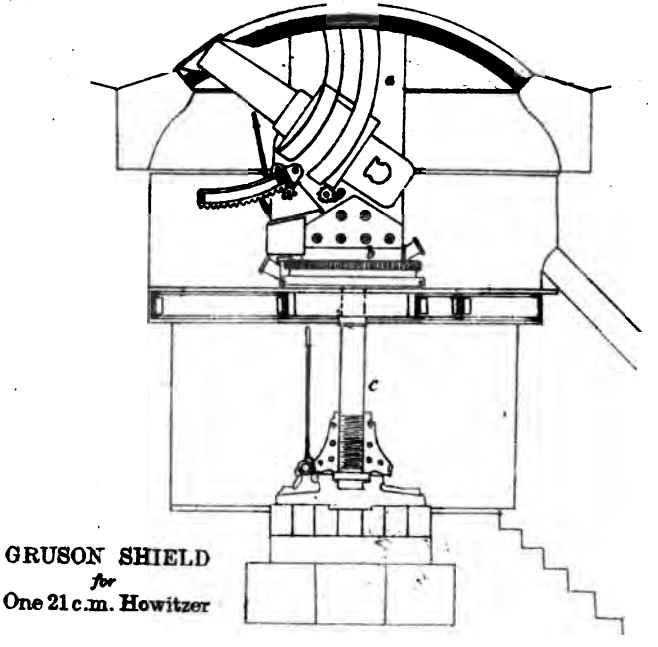
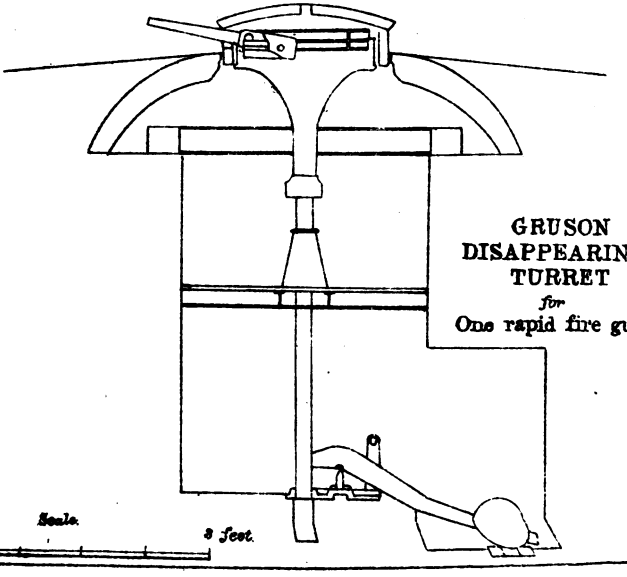


PLATE X



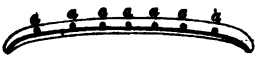
GRUSON SHIELD
for
One 21 c.m. Howitzer



GRUSON
DISAPPEARING
TURRET
for
One rapid fire gun

Scale.
1 0 3 feet.

Fig. 1.



Scale for Figs. 1 and 2.

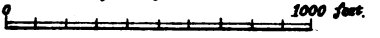


Fig. 2.

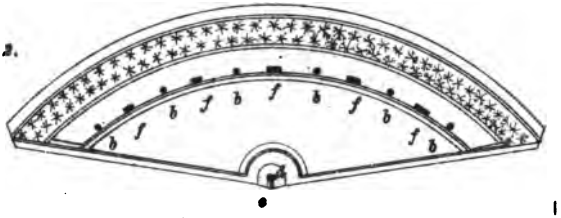
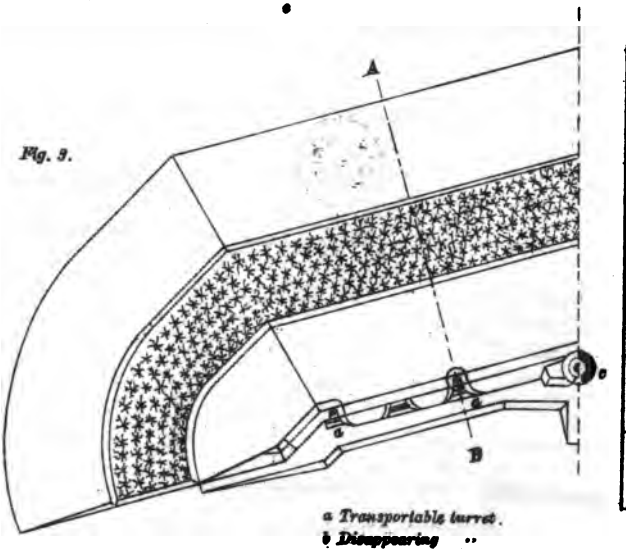
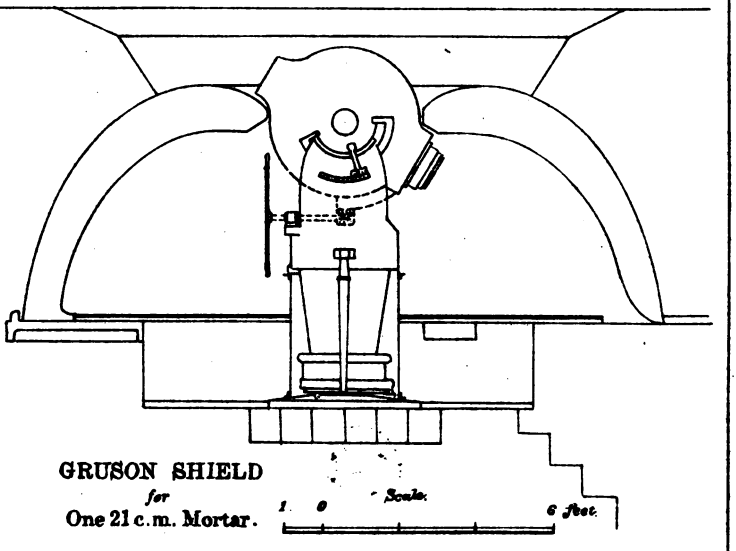


Fig. 3.



a Transportable turret.
b Disappearing ,,
c Shield for 12 c.m. r. f. howitzer.
d Turret for 12 c.m. gun.
e Shield ,, ,, ,, mortar.
f Bomb-proofs.

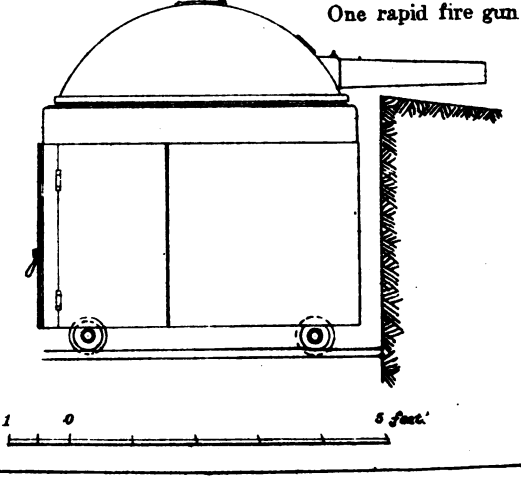
Fig. 4



GRUSON SHIELD
for
One 21 c.m. Mortar.

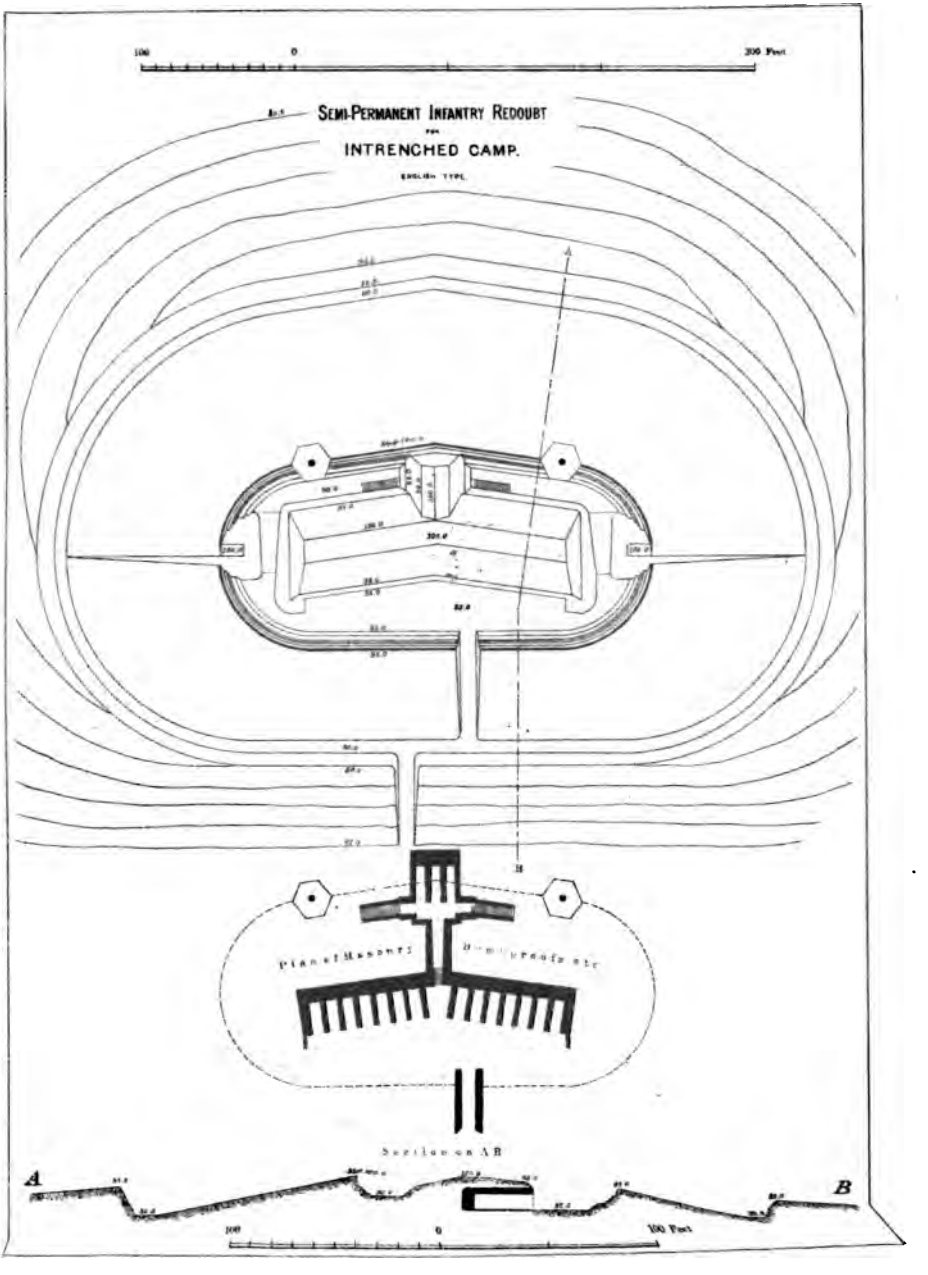
1 0 Scale. 6 feet.

GRUSON
TRANSPORTABLE
TURRET
for
One rapid fire gun.



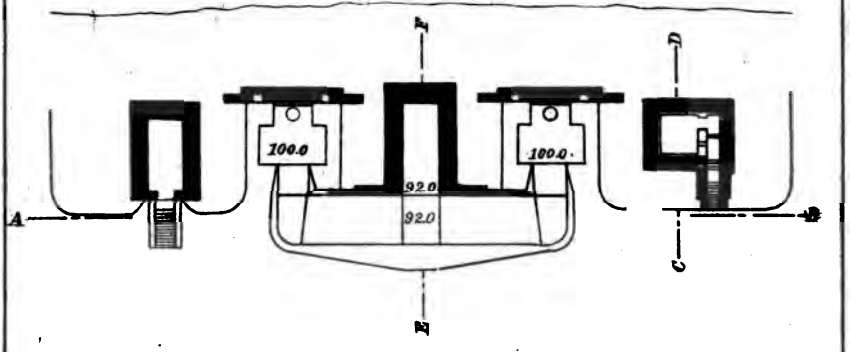
1 0 5 feet.

PLATE XIII


SEMI-PERMANENT INFANTRY REDOUBT
FOR
INTRENCHED CAMP.
ENGLISH TYPE.
A
B
Section on AB

SIEGE GUN BATTERY

English Type.



Elevation on A-B

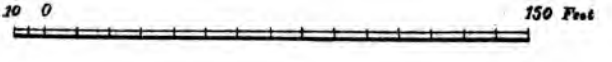


PLATE XV

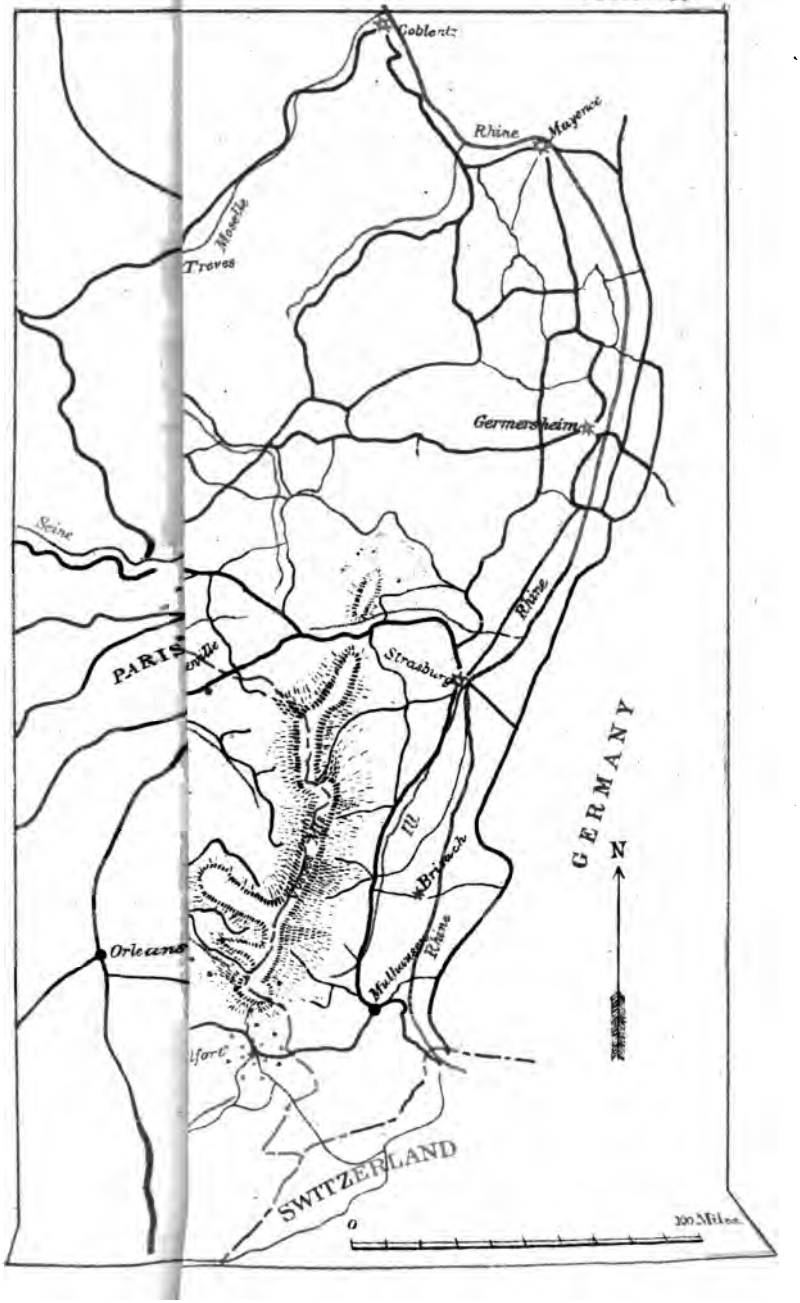

Coblentz
Rhine
Mayence
Moselle
Treves
Germersheim
Seine
PARIS
Rhine
Strasburg
GERMANY
N
Ill
Briesach
Rhine
Orleans
Mulhausen
SWITZERLAND
0
100 Miles

PLATE XV

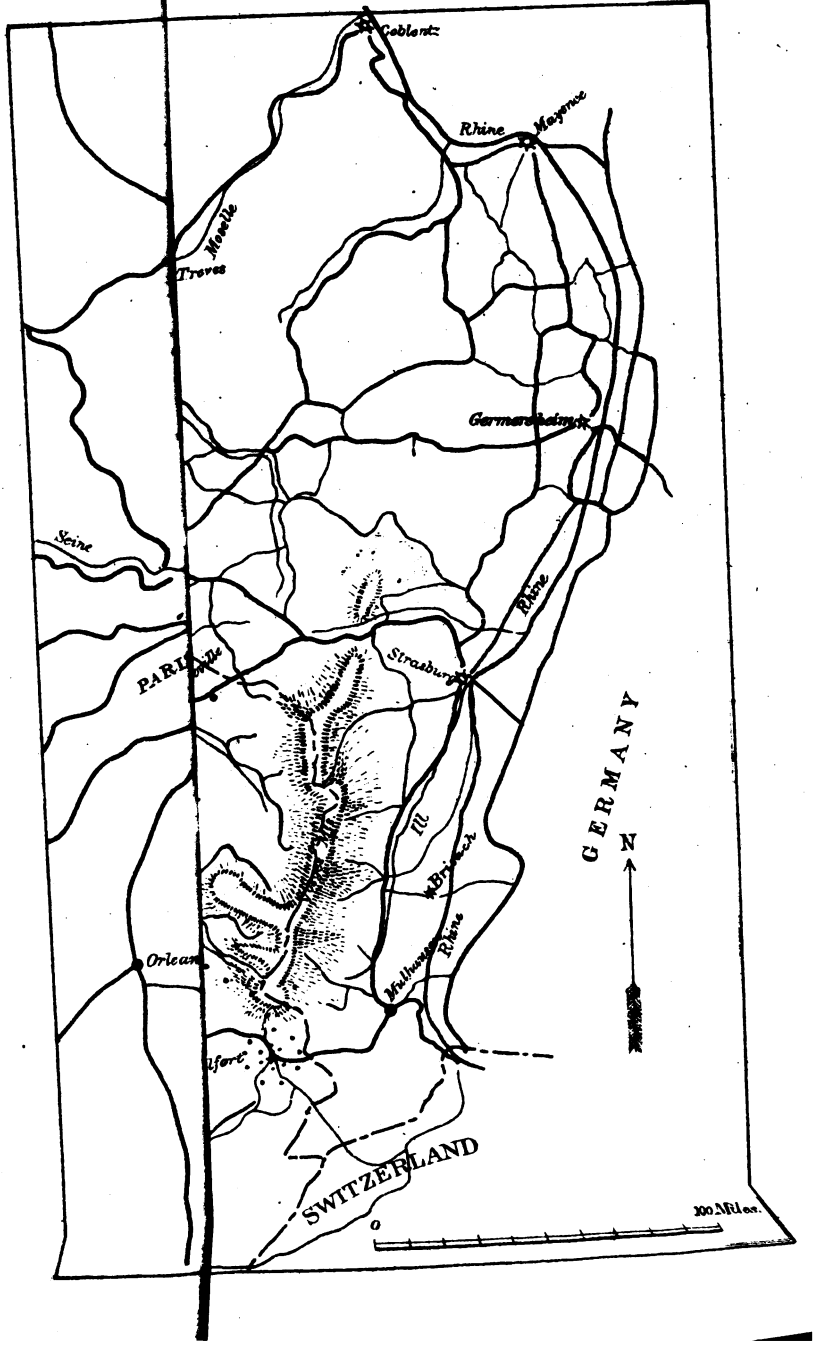
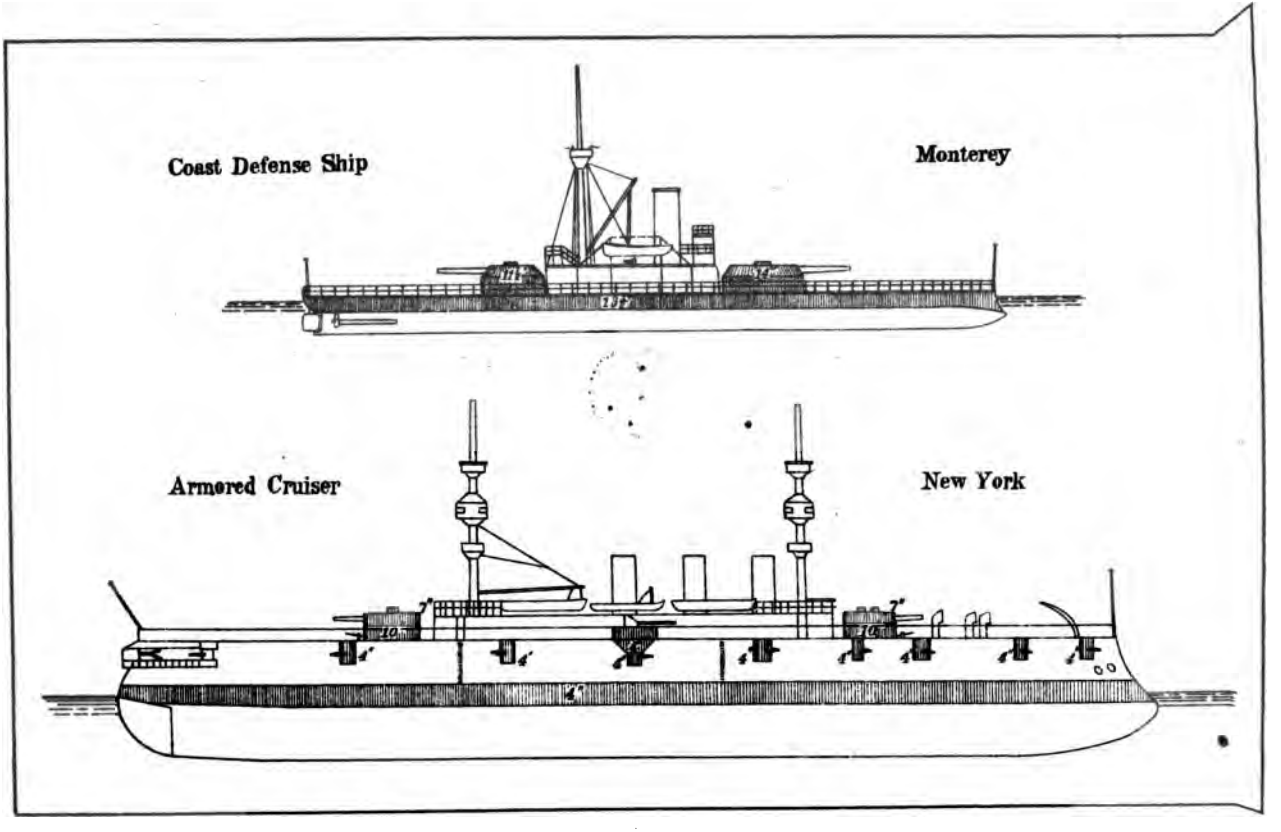

Coblentz
Rhine
Mayence
Moselle
Troyes
Seine
PARIS
Strasburg
Rhine
GERMANY
N
Ill
Brisach
Rhine
Orleans
Mulhausen
Basle
SWITZERLAND
0
100 Miles

PLATE XVII




UNIV.
OF
MICH.

PLATE XVIII

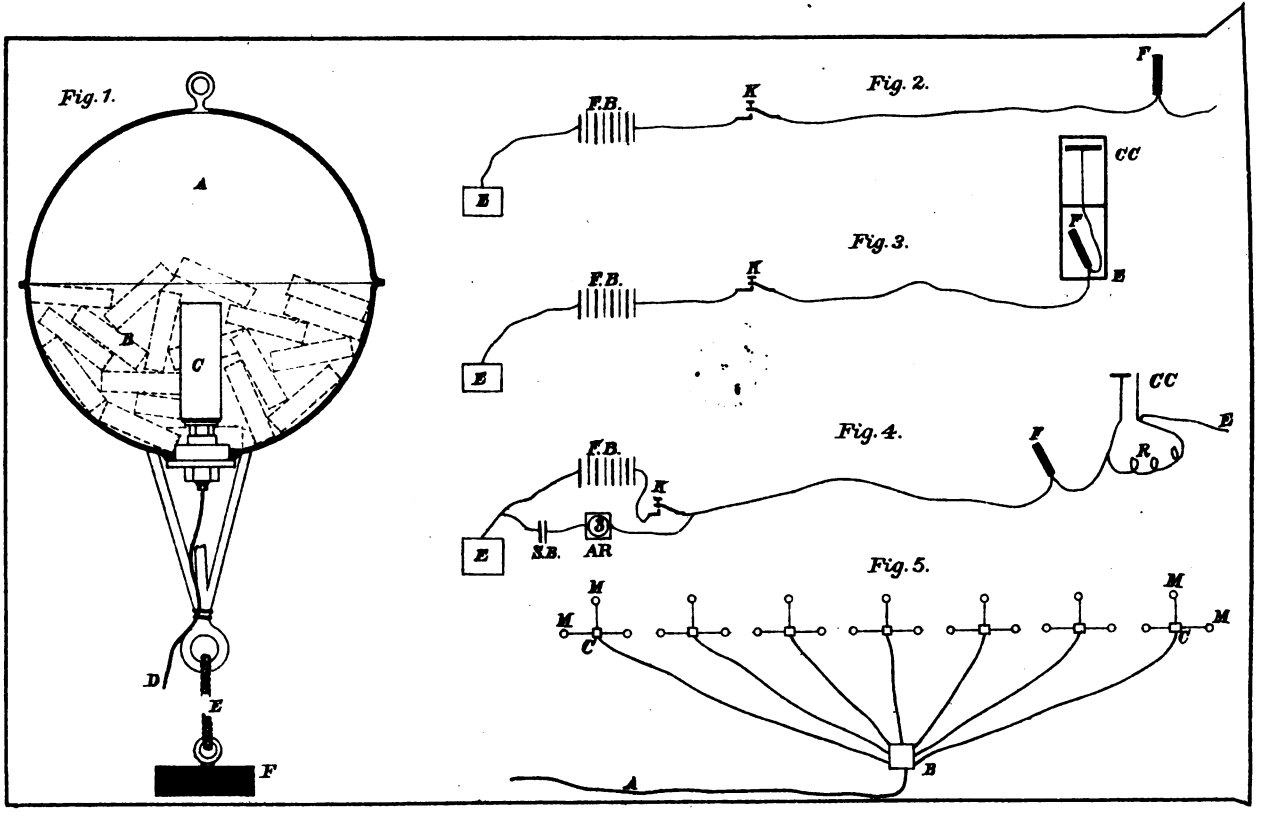


Fig. 1.
A
B
C
D
E
F
Fig. 2.
F.B.
K
E
F
CC
Fig. 3.
F.B.
K
E
CC
Fig. 4.
F.B.
K
E
S.B.
AR
F
R
Fig. 5.
M
C
B
A

PLATE XIX

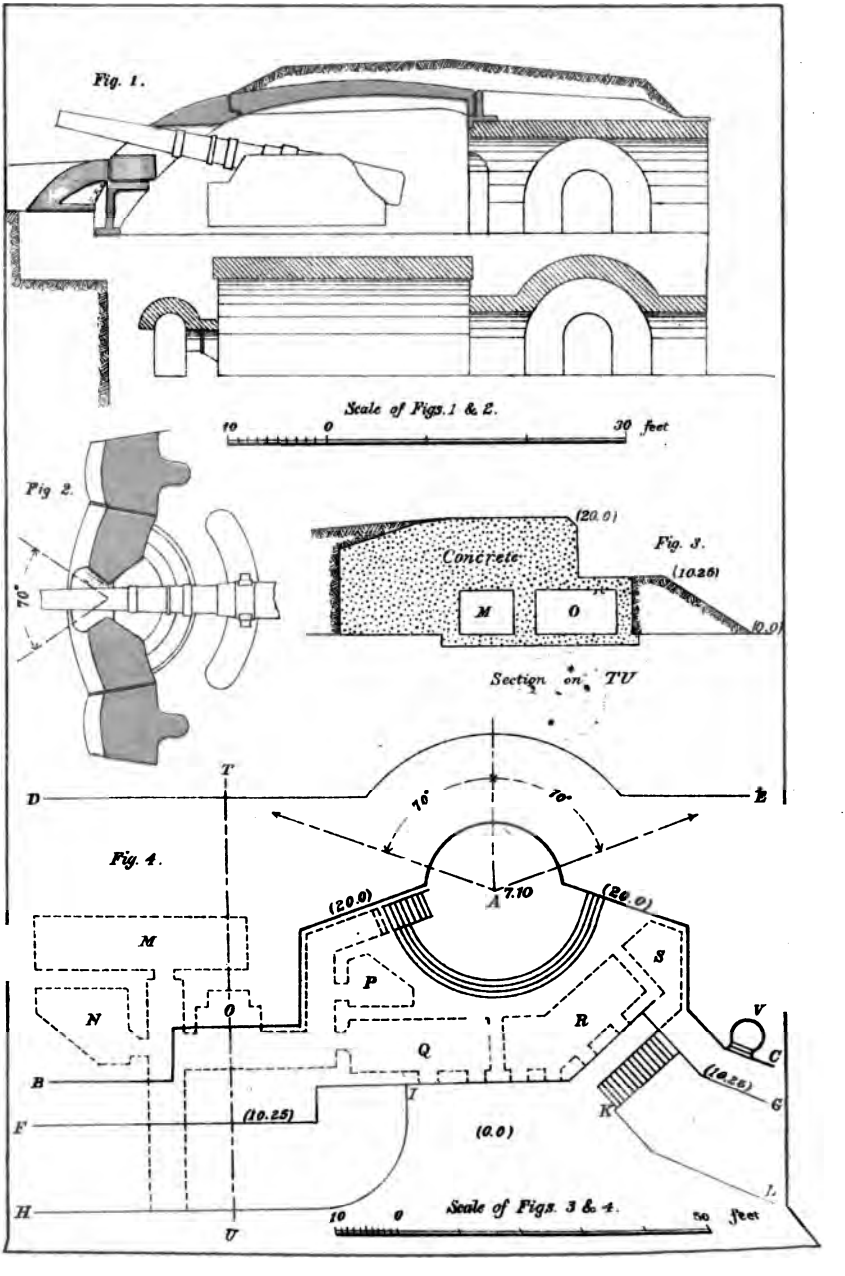
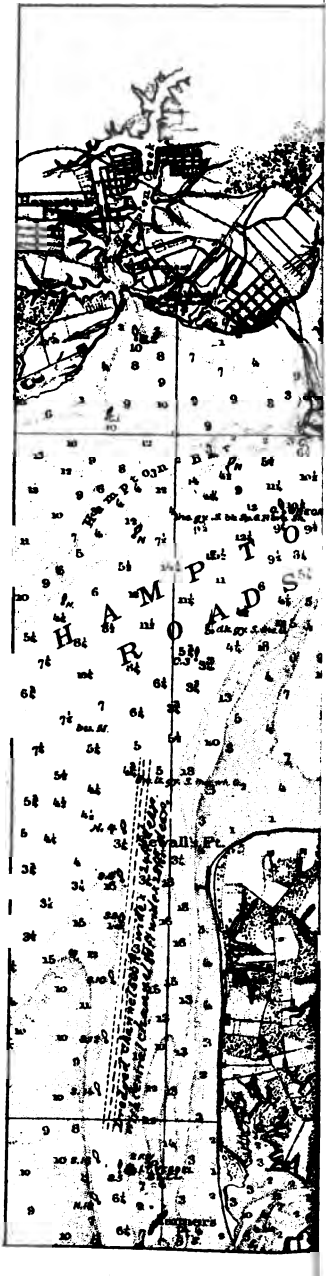


Fig. 1.
Scale of Figs. 1 & 2.
10 0 30 feet
Fig 2.
70°
(20.0)
Concrete
Fig. 3.
(10.26)
M
O
(0.0)
Section on TU
T
D
E
70°
70°
Fig. 4.
A
7.10
(20.0)
(20.0)
M
N
O
P
S
V
C
Q
R
B
(10.25)
I
K
(10.25)
G
F
(0.0)
L
H
U
10 0 Scale of Figs. 3 & 4. 50 feet


HAMPTON ROADS
Newall Pt.